Limnology and Trout Angling in Charlotte County Lakes, New Brunswick

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ABSTRACT

Limnological conditions were studied in eight lakes ranging in area from 20 to 73 ha. and in mean depth from 2.4 to 7.0 m. Summer thermal stratification occurred in five, while three were subject to mixing throughout by winds. August mean water temperatures varied from 14.9° to 22.0° C. Lowest mean dissolved-oxygen content was 71 per cent saturation although pronounced summer hypolimnal deficits developed in the stratified lakes. The lakes lie in a wooded area of poor soils, underlaid with granite rocks. Bicarbonate content ranged from 5.1 to 11.1 mg./1. Phosphate P was usually < 10 mg./cu. m., even in hypolimnia. Total P averaged about 15 mg./cu. m. with extremes of 5 and 34 mg. Allochthonous humic extractives coloured the waters in varying degree (5 to 59 p.p.m.). Adverse edaphic factors conditioned a low level of productivity. Desmids were qualitatively prominent in the plankton. Rooted aquatic vegetation was generally a minor feature. Dominant bottom organisms were *Hyalella*, *Amnicola* and sphaeriids in shallow and *Chaoborus* and chironomid larvae in deeper water. Fish fauna consisted of 18 species; at least speckled trout, eel, lake chub and banded killifish were common to all lakes.

Yields of speckled trout to anglers were assessed by creel censuses. Rate of capture averaged 0.3 per rod-hour over a seven-year period. Average annual yield was 0.65 kg./ha. Trout in their third (22 cm., 130 g.) and fourth (29 cm., 263 g.) years of age made up 85 per cent of catches. Growth rates were similar in all lakes. Introduced trout contributed little unless planted at angling size and cropped within a year. The supply of young native trout was apparently sufficient to utilize full trout-producing capacities of these lakes.

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INTRODUCTION

THE SPECKLED TROUT, *Salvelinus fontinalis* (Mitchill), is one of the principal sport fish in the freshwaters of the Atlantic maritime provinces of Canada. As a result of its popularity the species has been subjected to an ever-increasing angling pressure, and sportsmen generally contend that stocks of trout have progressively declined. For much of the area, however, there are insufficient data upon the present, let alone the past, yield of trout to anglers and upon the conditions in streams and lakes to substantiate or refute this contention. Where habitats have been detrimentally altered and where the selective angling for trout or other events have permitted a dominance of undesirable fish to develop, it may reasonably be expected that stocks of trout have declined and even become exhausted. On the other hand, a division of equally large total catches among an increasing number of anglers has no doubt led, in many cases, to the false impression that an area was yielding less trout than formerly.

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In 1939 a study was begun in eight lakes of Charlotte County, southwestern New Brunswick, to explore the limnological conditions and to assess the yield of speckled trout to the anglers. By this study a step was taken toward gaining the needed information to pass judgment upon the above contention and, of immediate concern, to obtain data that would serve as a guide to the development of practical measures to maintain and increase stocks of trout in these and other lakes of the same general character.

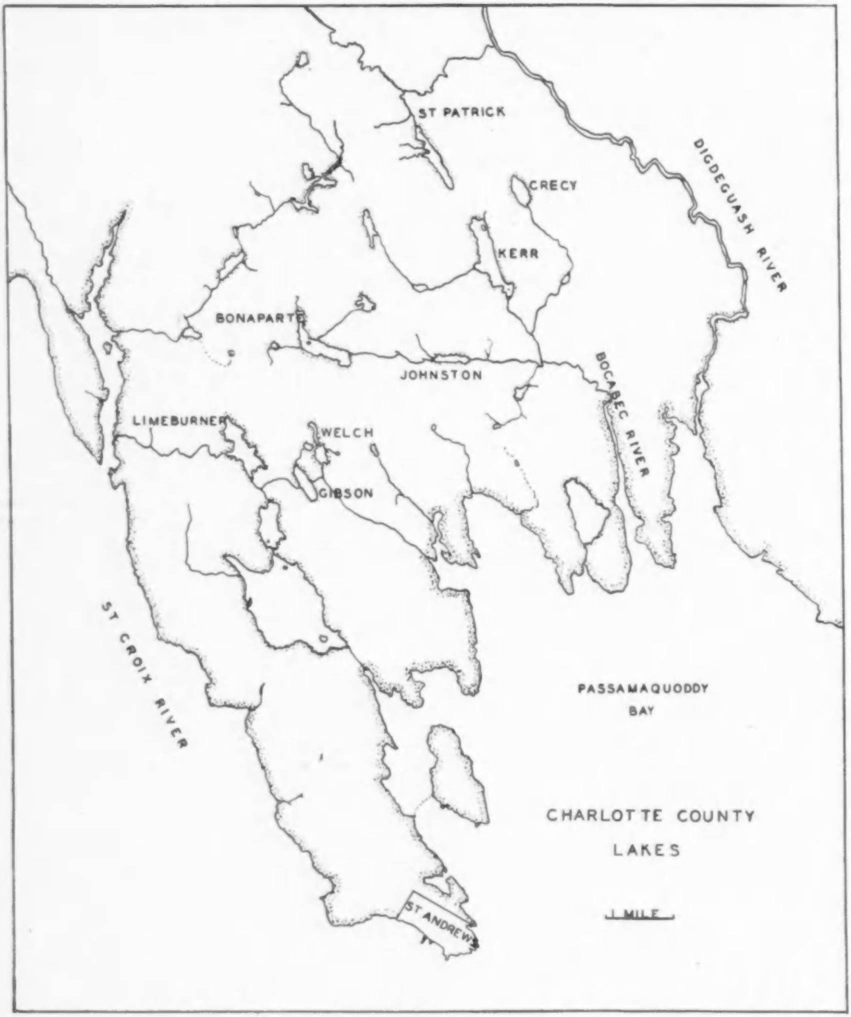

FIGURE 1. Map of southwestern Charlotte County, New Brunswick, showing location of investigated lakes.

During the ten-year period prior to 1939 seven of the eight lakes were stocked, certain of them almost every year, with hatchery-reared speckled trout. A definite schedule of stocking was continued during this study and, by marking the fish by fin-clipping, assessments were made of the contribution that the introduced trout made to the anglers' catches.

LIMNOLOGY

Location of the Lakes

The eight lakes—Bonaparte, Crecy, Gibson, Johnson, Kerr, Limeburner, St. Patrick, Welch—are situated in Charlotte County, southwestern New Brunswick, at about 45° N. Lat. and 67° W. Long. All of them are within eight kilometres (five miles) of salt water, and none lies at an elevation over 100 metres above sea-level. The location of the lakes with respect to each other is shown in Figure 1.

Character of the Drainage Area

The drainage area feeding the lakes is small, covering only about 65 square kilometres (25 square miles), yet four short drainage systems are involved (Figure 1). The outflow from St. Patrick Lake drains into the Digdeguash River, those from Crecy, Kerr, Bonaparte and Johnson Lakes into the Bocabec River, and that from Welch and Gibson Lakes into the Chamcook system. Originally the outflow from Limeburner Lake drained only into the St. Croix River, but at present it is partially diverted by a ditch into the Chamcook system.

The terrain is hilly, covered largely by a climax forest of spruce, fir, cedar, beech, maple and birch (Claridge, 1926). Sweet gale and alder are the dominant shrubs of the immediate shoreline. Swamps and bogs cover only small areas but they have an important effect upon the lakes through their contribution of organic matter to the drainage waters.

The lakes lie in a region of Devonian granite, granite gneiss and gabbro (Can. Dept. Mines, Geol. Surv., Map 259A, 1931). The igneous rocks have weathered to give only thin and relatively unproductive soils. At no time has there been more than a small fraction of the land in the drainage area of the lakes cleared for farming, and there has been a progressive abandonment in recent times of homesteads established in past years.

As a result of the character of the underlying rock formation and of the soils, springs are few and surface drainage accounts for most of the run-off. Many tributary streams are intermittent, while others reach a low level in summer. The average annual fluctuation in lake levels is one to two feet.

Morphometry of the Lakes

Area and depth measurements were obtained from surveys made over ice. The surveys resulted in quite accurate maps of large scale with depth contours well defined (Figures 8-15, at the end of the paper). The number of soundings made to establish the contours ranged from 39 in Crecy to 193 in Limeburner Lake, the total for the lakes being 891.

Morphometric data for the eight lakes are presented in Table I. Volume, mean depth, and volume and shore development were estimated from formulae given by Birge and Juday (1914). The areas of the lakes range from 15 to 73 hectares (36 to 180 acres), and the maximum depth from 4 to 21 metres. The minimum mean depth is 3.8 metres in Crecy and the maximum 7.0 metres in Bonaparte Lake. Thus, although the lakes may all be classed as small, there exists variety in their morphometry.

TABLE I. Morphometry of Charlotte County lakes.

	Bonaparte	Crecy	Gibson	Johnson
Area, *ha.*(*acres*)	42.8(105.8)	20.4(50.4)	24.0(59.4)	14.6(36.1)
Maximum depth, *m.*(*ft.*)	21.0(68.9)	3.8(12.5)	6.1(20.0)	12.0(39.4)
Mean depth, *m.*(*ft.*)	7.0(23.0)	2.4(7.8)	4.0(13.0)	5.8(19.1)
Volume, *cu.m.*	2.94×10^6	0.49×10^6	0.95×10^6	0.85×10
(*cu.ft.*)	(103.76×10^6)	(17.18×10^6)	(33.31×10^6)	(30.03×10)
Perimeter, *km.*(*mi.*)				
Without islands	4.96(3.08)	1.89(1.17)	2.38(1.48)	2.04(1.27)
With islands	5.27(3.27)	...	...	...
Volume development	1.00	1.89	1.97	1.48
Shore development,				
Without islands	2.18	1.18	1.37	1.51
With islands	2.32	...	...	...

Physical and Chemical Environments

TEMPERATURE OF THE WATER. Vertical series of water temperatures were obtained during the open-water season in 1941 and 1942 at metre intervals of depth in the deepest part of each lake. Winter water temperatures are available only for Bonaparte, Crecy and Gibson Lakes. A Negretti and Zambra reversing thermometer, calibrated to 0.2°C., was employed. Temperature data are presented in Tables II and III (pp. 388-389) and Figures 2–4 (pp. 390, 391, 392).

"The Atlantic Provinces, which might be expected to have a purely maritime climate, are served principally by air moving eastward off the North American continent. The climate is, therefore, continental in character" (Canada Year Book, 1949, p. 43). However, the summer climate of the region in which the Charlotte County lakes are located is somewhat moderated by the cool waters of the adjacent Bay of Fundy (Table IV). The maximum surface temperature recorded for the eight lakes was 23.7°C. in Welch on July 24, 1941, and in Gibson on August 13, 1942. On the latter date the mean temperature of water in Gibson Lake reached 22.0°C., which was the highest for any of the lakes. In Bonaparte and Johnson Lakes, with thermally stratified waters, the mean water temperature in July and August was decidedly lower, being as low as 13.9°C. in Johnson on August 7, 1942. On the whole the lakes present a relatively cool environment in mid-summer.

The lakes may be separated into three groups by reference to the vertical temperature patterns of their waters in mid-summer. Bonaparte, Johnson and Welsh Lakes exhibited the familiar thermal stratification into epilimnion, thermocline and hypolimnion (Figures 2 and 3). The epilimnion in these lakes extended to a depth of only 3 or 4 metres during August. However, at the same season in Kerr and Limeburner Lakes, which are larger and subject to greater wind action, this warm surface stratum was 7 to 8 metres in depth,

TABLE I (*continued*).

	Kerr	Limeburner	St. Patrick	Welch
Area, *ha.*(*acres*)	73.0(180.3)	55.2(136.3)	30.6(75.7)	18.0(44.6)
Maximum depth, *m.*(*ft.*)	12.0(39.4)	10.0(32.8)	5.8(19.8)	11.4(37.4)
Mean depth, *m.*(*ft.*)	4.7(15.4)	4.4(14.6)	3.3(10.8)	2.4(7.8)
Volume, *cu.m.*	3.41 × 10	2.40 × 10	1.00 × 10	0.43 × 10
(*cu.ft.*)	(120.43 × 10)	(84.71 × 10)	(35.42 × 10)	(15.01 × 10)
Perimeter, *km.*(*mi.*)				
Without islands	5.96(3.70)	5.02(3.11)	4.28(2.66)	3.67(2.26)
With islands	6.83(4.24)	...	5.10(3.17)	4.92(3.06)
Volume development	1.18	1.33	1.71	0.60
Shore development,				
Without islands	1.99	1.70	2.16	2.50
With islands	2.28	...	2.57	3.36

below which the temperature dropped in a thermoclinal manner almost to the bottom (Figure 4). The water was not sufficiently deep in either of these lakes for a well-defined hypolimnion. In Crecy, Gibson and St. Patrick Lakes, with their relatively shallow depths, the waters were subject to complete mixing by winds during the summer and any thermal stratification was weak and temporary (Figures 2 and 4).

The lowest mean mid-summer temperatures were found in Bonaparte and Johnson Lakes. They reflected a well-established thermal stratification and a relatively small percentage (44 per cent on August 17 and 56 per cent on August 11, 1942) of the total volume of the lake in the epilimnion. Although the epilimnion was no thicker in Welch, it made up 80 per cent of the volume of the lake (August 13, 1942). Accordingly, the mean water temperature in this lake was higher than in the others with stratified waters. Rather it approached that found in the five lakes in which all or nearly all of the water was subject to mixing under the influence of summer winds and as a result was warmer throughout.

The lakes freeze over for the winter in late November or early December, with some variation in date between the individual lakes and from year to year. The ice does not usually disappear until late April, although areas of open water, especially near affluent and effluent streams, are often in evidence well in advance

TABLE II. Summer temperatures of the lakes, in degrees Centigrade.

	Air temp.	Surface water temp.	Bottom water temp.	Mean temp. of lake	Percentage of volume over 20°
BONAPARTE LAKE					
1941 24/VI	13.5	19.7	5.65	14.5	...
23/VII	24.0	22.85	5.95	16.1	34
10/IX	14.7	16.7	6.35	14.2	...
1942 27/V	12.6	16.9	4.95	11.1	...
14/VII	24.8	21.6	5.2	14.1	34
17/VIII	21.0	21.55	5.4	14.9	44
18/IX	15.5	18.8	5.55	14.1	
CRECY LAKE					
1942 19/V	18.0	16.0	14.6	15.5	...
8/VII	22.1	21.1	20.6	20.9	100
12/VIII	24.7	21.9	20.75	21.2	100
16/IX	15.0	18.35	18.45	18.4	...
GIBSON LAKE					
1941 25/VI	16.0	19.5	15.5	18.0	...
23/VII	21.0	21.7	17.8	21.0	82
10/IX	14.7	16.9	16.8	16.9	...
1942 26/V	13.2	15.0	11.95	14.5	...
13/VII	24.0	21.2	16.45	20.0	47
13/VIII	23.9	23.7	20.9	22.0	100
17/IX	21.9	19.55	18.6	18.9	
JOHNSON LAKE					
1941 24/VI	18.3	21.6	5.95	15.4	56
22/VII	22.4	22.4	6.3	16.2	56
9/IX	19.8	17.1	7.25	14.4	...
1942 18/V	19.6	15.7	4.8	10.3	...
7/VII	19.0	20.15	5.55	13.9	25
11/VIII	17.1	20.75	5.9	16.2	56
15/IX	20.2	18.5	6.2	16.0	...
KERR LAKE					
1941 24/VI	16.8	20.3	14.4	18.5	53
22/VII	25.8	21.4	14.0	20.2	67
9/IX	16.8	16.95	16.3	16.6	...
1942 19/V	15.9	14.4	10.35	13.4	...
7/VII	24.3	21.9	11.6	20.0	67
11/VIII	18.2	21.05	13.0	20.7	98
15/IX	24.1	20.0	12.7	18.8	...
LIMEBURNER LAKE					
1941 26/VI	14.7	19.0	14.25	18.4	...
24/VII	21.7	22.6	14.95	21.5	80
11/IX	17.9	16.9	16.3	16.5	...
1942 26/V	22.5	17.8	11.1	15.4	...
13/VII	21.9	20.9	14.1	19.6	70
13/VIII	24.1	23.1	14.7	21.4	...
17/IX	20.3	19.25	18.0	18.7	99

TABLE II (*continued*).

	Air temp.	Surface water temp.	Bottom water temp.	Mean temp. of lake	Percentage of volume over 20°
ST. PATRICK LAKE					
1941 15/IX	19.2	16.7	15.1	15.9	...
1942 18/V	21.7	15.8	10.9	13.5	...
8/VII	22.9	20.6	16.15	19.8	55
12/VIII	21.1	20.9	19.5	20.6	90
16/IX	14.9	18.3	17.75	18.2	...
WELCH LAKE					
1941 26/VI	13.9	18.75	7.65	17.6	...
24/VII	25.5	23.7	7.9	21.0	80
11/IX	20.4	17.2	8.8	16.2	...
1942 26/V	17.4	16.7	5.15	14.2	...
13/VII	24.9	21.6	5.05	18.2	58
13/VIII	24.9	22.1	6.4	19.2	80
17/IX	19.1	18.45	6.75	17.1	

of the general break-up. With strong winds the ice disappears almost simultaneously from the several lakes, but with calm weather, such as in 1943, a number of days may intervene between the break-up dates. Recorded dates for ice formation and disappearance are given in Table V. On the average the lakes are ice-bound for four and one-half months out of each year.

Winter water temperatures for Bonaparte, Crecy and Gibson Lakes are given in Table III. The shallower Crecy and Gibson Lakes apparently froze over when the mean temperature of the water was close to 4°C., while in larger

TABLE III. Winter water temperatures of the lakes, in degrees Centigrade.

Depth[a] (*m.*)	Bonaparte	Crecy			Gibson	
	Jan. 15, 1937	Jan. 7, 1947	March 17, 1947	Dec. 27, 1948	March 17, 1947	March 19, 1948
0.5	2.6	3.45	3.8	3.5	1.5	1.75
1	...	...	...	3.9	...	...
2	...	4.0	4.0	3.9	3.25	4.0
3	...	...	4.05	4.0	4.15(?)	4.1
3.5	...	4.15	4.15	4.2	...	...
4	...				4.0	4.1
5	3.1				4.05	4.5
5.5	...				...	5.2
6	...				4.15	
10	3.3					
15	3.45					
20	3.55					

[a]Depth measured from lower edge of ice.

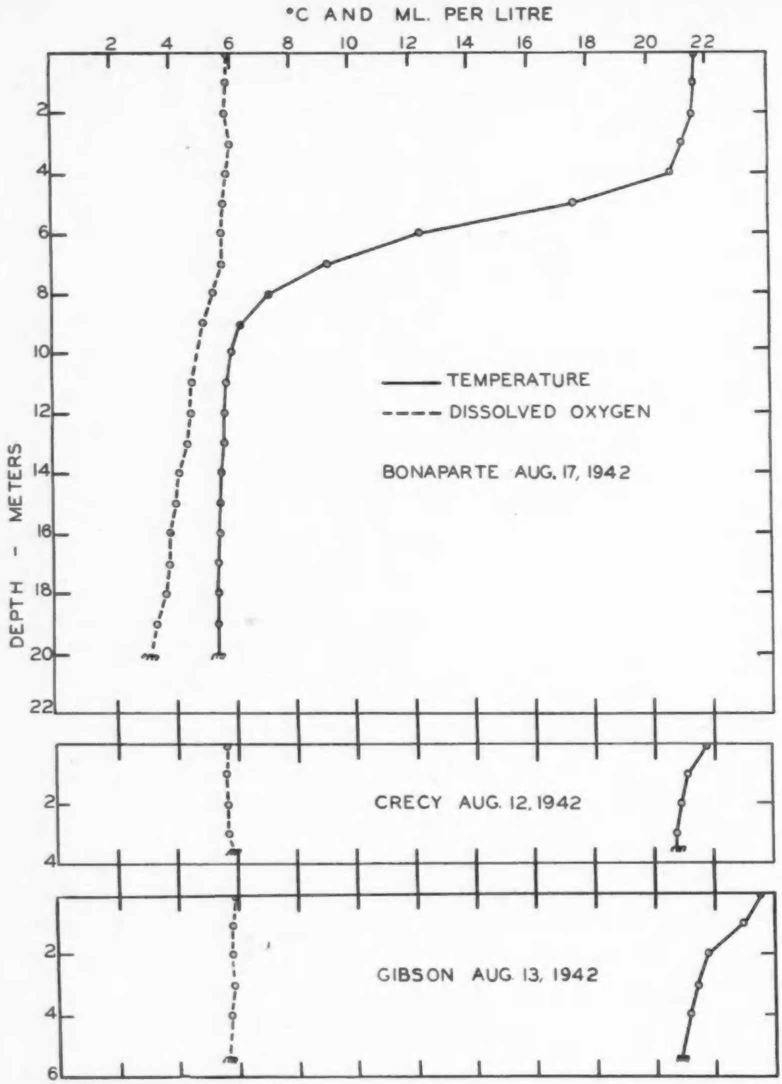

FIGURE 2. Temperature and dissolved oxygen curves for Bonaparte, Crecy and Gibson Lakes.

Bonaparte Lake it was depressed to a somewhat lower level by wind circulation. It is interesting to note the cold equable thermal environment that exists in the bottom waters of Bonaparte and, presumably, Johnson Lakes throughout the year (Table II).

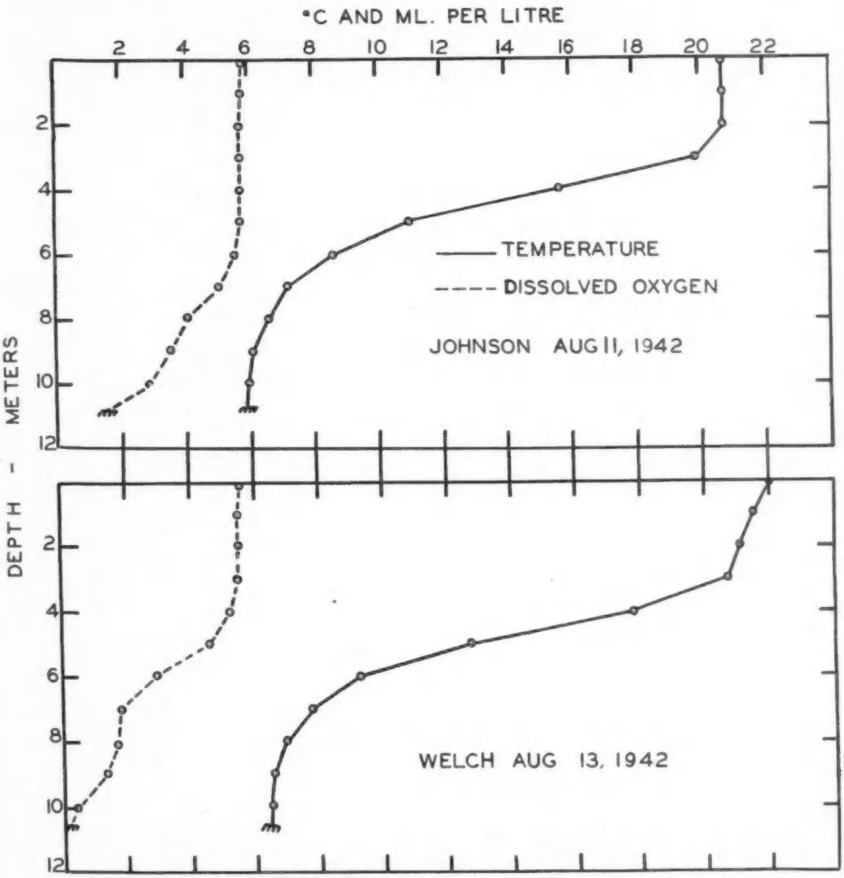

FIGURE 3. Temperature and dissolved oxygen curves for Johnson and Welch Lakes.

COLOUR OF WATER. An important environmental factor in certain of the eight lakes is the brown colour of the water. Measurements of this colour were made by comparison with the conventional platinum-cobalt standards which simulate the natural brown hue quite closely. Values, expressed as milligrams per litre (p.p.m.) of platinum, are given in Table VI and it may be noted that a considerable range of colour (< 5 to 59) existed among the lakes, with Bonaparte, Johnson, St. Patrick and Welch Lakes consistently having the highest values.

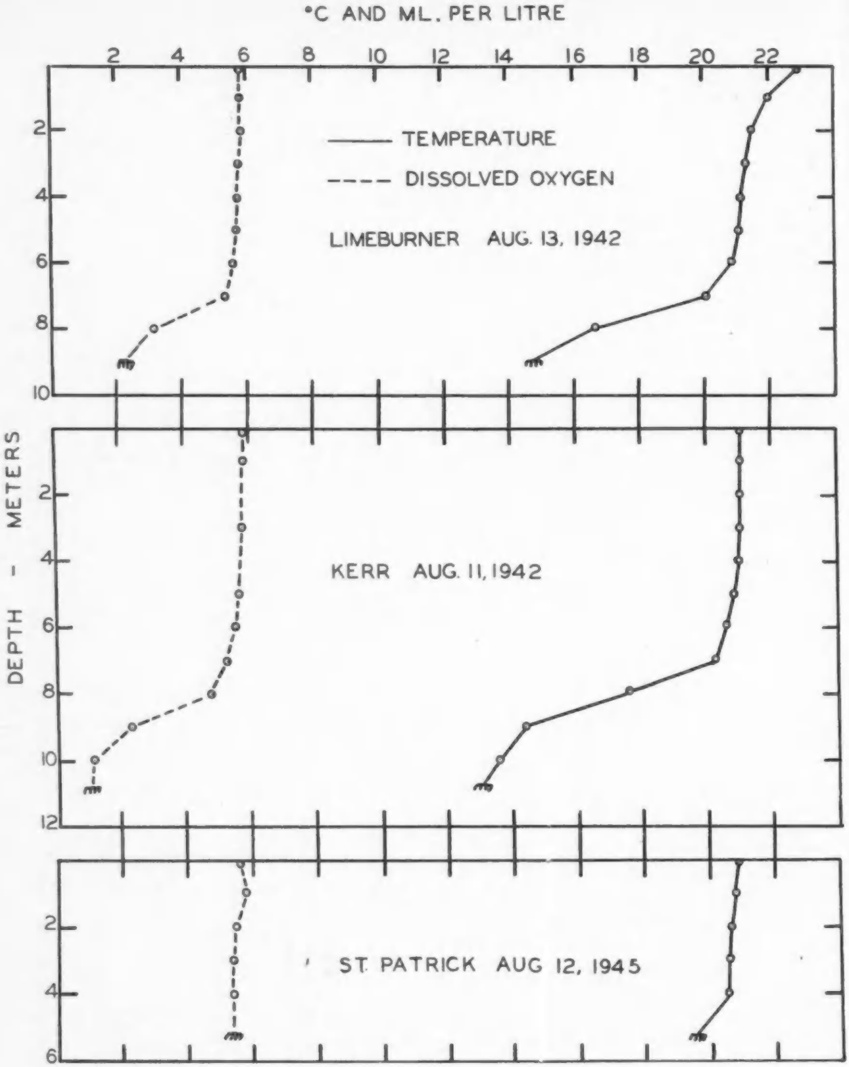

FIGURE 4. Temperature and dissolved oxygen curves for Limeburner, Kerr and St. Patrick Lakes.

TABLE IV. Mean air temperature, Atlantic Biological Station, St. Andrews, N.B., in degrees Fahrenheit.

Year	July		August	
	Maximum	Minimum	Maximum	Minimum
1940	75.1	53.7	74.9	50.2
1941	73.7	52.7	70.2	51.6
1942	72.2	52.3	73.4	52.5
1943	73.2	52.4	71.3	53.5
1944	74.8	54.3	77.9	55.6
1945	74.7	54.6	74.5	53.9
1946	72.8	52.4	71.3	53.9
1947	71.4	57.5	73.8	55.2
1948	70.1	53.8	71.7	55.3

The brown colour is due to the presence of organic substances, in colloidal and dissolved form, that originate from the incomplete decomposition of plant materials, usually under acid and anaerobic conditions. Although some develop within (autochthonous), the greater part of these materials are derived from outside the lakes (allochthonous) and are brought in by surface drainage from bogs, swamps and acid soils. Accordingly, the intensity of colour may be expected

TABLE V. Dates upon which ice finally formed and disappeared from Charlotte County lakes.

I Ice formed

	1941	1943	1944	1946	1948
Bonaparte	Dec. 12	Dec. 11	Dec. 9	Dec. 17	Dec. 16
Crecy	Nov. 26	Nov. 29	Nov. 23	Nov. 28	Dec. 12
Gibson	Dec. 11	Dec. 8	Dec. 5	Dec. 3	Dec. 15
Johnson	Nov. 26	Nov. 29	Dec. 5	Nov. 28	Dec. 15
Kerr	Dec. 11	Dec. 11	Dec. 9	. . .	Dec. 16
Limeburner	Dec. 12	Dec. 8	Dec. 9	Dec. 3	Dec. 16
St. Patrick	Nov. 26	Dec. 4	Dec. 5	. . .	Dec. 15
Welch	Nov. 26	Nov. 30	Dec. 5	Nov. 28	Dec. 15

II Ice disappeared

	1941	1942	1943
Bonaparte	Apr. 22	Apr. 22-23	May 1
Crecy	"	"	Apr. 26
Gibson	"	"	Apr. 26
Johnson	"	"	Apr. 29
Kerr	"	"	Apr. 29
Limeburner	"	"	Apr. 26
St. Patrick	"	"	Apr. 28
Welch	"	"	Apr. 26

to vary with the amount of surface drainage and with the extent of the areas in the drainage system where the extractives may form. The values determined in July, 1942, were higher than those in July, 1941. The differences were associated with a greater precipitation during June and July in 1942 (7.6 in. of rain in 1942 at St. Andrews, New Brunswick, as against 2.9 in. for the same period in the previous year). The variation in colour values among the lakes also agreed well with the extent of swamp and bog areas involved in the several drainage systems.

TABLE VI A. Colour of water, in parts per million.

Lake	Depth (*m.*)	Dates and values			
Bonaparte		July 7/41	May 27/42	July 14/42	Sept. 18/42
	0	20	24	24	19
	20	23	26	25	24
Crecy		July 14/41	May 19/42	July 8/42	Sept. 16/42
	0	5	5	5	5
	3.5	5	5	5	5
Gibson		July 3/41	May 20/42	July 13/43	Sept. 17/42
	0	9	15	16	11
	5.5	9	15	15	11
Johnson		July 9/41	May 18/42	July 7/42	Sept. 15/42
	0	21	25	26	29
	11	20	25	25	42
Kerr		July 9/41	May 19/42	July 7/42	Sept. 15/42
	0	9	15	18	15
	11	9	15	19	...
Limeburner		July 3/41	May 26/42	July 13/42	Sept. 17/42
	0	5	10	9	9
	9	5	10	14	20
St. Patrick		July 9/41	May 18/42	July 8/42	Sept. 16/42
	0	25	31	31	24
	5	...	30	32	24
Welch		July 7/41	May 26/42	July 13/42	Sept. 17/42
	0	19	28	28	16
	11	40	33	49	59

Obviously the brown colour of the water has an effect upon the penetration of light. Birge and Juday (1932) found that only about 20 per cent of the total incident radiation (zenith sun) reached a depth of one metre in Wisconsin lakes with colour values ranging from 20 to 30. In clear lakes with colour approximately zero about 40 per cent of the incident radiation penetrated to the same depth. Thus the zone for effective photosynthesis of phytoplankters varied considerably in depth among the Charlotte County lakes, and in any one of them within and between years.

In addition to modifying light penetration into the water, the brown colour affected the lake environments directly or indirectly in a number of other ways to be described below.

OXYGEN CONSUMED. The method outlined by the American Public Health Association (1936) was followed in the determination of oxygen-consumed values. Results expressed as milligrams per litre (p.p.m.) of oxygen consumed from the permanganate digestion of 100 millilitres of water are set forth in Table VI.

TABLE VI B. Oxygen consumed, in parts per million.

Lake	Depth(*m.*)	Dates and values	
Bonaparte		July 7/41	May 27/42
	0	7.4	6.2
	10	7.4	...
	20	7.6	6.8
Crecy		July 14/41	May 19/42
	0	5.4	5.2
	3.5	...	5.1
Gibson		July 3/41	May 20/42
	0	7.1	6.9
	5.5	7.4	6.2
Johnson		July 9/41	May 18/42
	0	6.7	7.5
	5	6.8	...
	11	6.9	7.3
Kerr		July 9/41	May 19/42
	0	5.4	7.0
	5	5.7	...
	11	6.5	7.0
Limeburner		July 3/41	May 26/42
	0	5.6	4.4
	9	4.8	4.7
St. Patrick		July 9/41	May 18/42
	0	9.0	9.2
	5	...	8.0
Welch		July 7/41	May 26/42
	0	8.6	8.3
	5	8.1	...
	11	8.8	8.1

Oxygen-consumed values provide a measure, albeit imperfect, of the amount of organic matter in the water of the lakes since only the more readily oxidizable organic carbon (not nitrogen) is affected by the digestion. According to Juday and Birge (1932) the oxidizable carbon amounts to about 40 per cent of the total in lake waters.

A strong and statistically significant positive correlation existed between the values for oxygen consumed and colour ($r = 0.874$ with 27 d.f.). The lowest values were determined for the clear waters of Crecy and Limeburner Lakes and the highest in the most markedly stained waters of St. Patrick and Welch Lakes. The correlation suggests that about 76 per cent of the potentially oxidizable organic matter was that which imparted colour to the water. As noted

TABLE VII. Dissolved oxygen content in millilitres per litre, with percentage saturation in brackets.

		Surface	Bottom	Mean for lake	Percentage of volume with > 3.5 *ml./l.*
BONAPARTE LAKE					
1941	24/VI	6.00(93)	4.76(54)	6.07(85)	...
	23/VII	5.82(96)	4.14(47)	5.66(82)	...
	10/IX	6.11(89)	2.54(29)	5.88(71)	2
1942	27/V	6.99(102)	5.66(63)	6.89(89)	...
	14/VII	5.95(96)	3.89(44)	5.73(79)	...
	17/VIII	5.88(94)	3.18(36)	5.42(76)	2
	18/IX	5.99(91)	1.92(22)	5.29(73)	11
CRECY LAKE					
1942	19/V	6.91(99)	6.97(97)	6.96(99)	...
	8/VII	5.79(92)	5.90(93)	5.83(93)	...
	12/VIII	5.77(93)	5.91(93)	5.79(92)	...
	16/IX	6.09(92)	6.12(92)	6.13(93)	...
GIBSON LAKE					
1941	25/VI	6.16(95)	6.07(87)	6.18(93)	...
	23/VII	6.06(98)	5.50(84)	5.95(95)	...
	10/IX	6.48(95)	6.45(94)	6.47(95)	...
1942	26/V	6.95(98)	6.51(86)	6.89(96)	...
	13/VII	6.06(97)	5.32(77)	6.04(94)	...
	13/VIII	5.93(99)	5.66(90)	5.82(94)	...
	17/IX	6.10(94)	5.93(89)	6.02(92)	...
JOHNSON LAKE					
1941	24/VI	5.92(95)	4.92(56)	5.92(83)	...
	22/VII	5.74(94)	4.40(51)	5.64(81)	...
	9/IX	6.28(92)	4.23(50)	6.00(83)	...
1942	18/V	7.04(101)	4.41(49)	6.60(84)	...
	7/VII	5.82(91)	2.72(31)	5.59(77)	2
	11/VIII	5.84(92)	1.53(20)	5.35(77)	6
	15/IX	6.02(90)	0.96(11)	5.17(74)	10
KERR LAKE					
1941	24/VI	5.99(94)	5.32(74)	6.02(91)	...
	22/VII	5.85(94)	3.38(47)	5.85(94)	1
	9/IX	6.33(93)	6.31(91)	6.33(93)	...
1942	19/V	7.29(101)	6.64(84)	7.30(104)	...
	7/VII	5.90(95)	1.53(20)	5.68(88)	2
	11/VIII	5.81(93)	1.11(15)	5.64(90)	2
	15/IX	6.16(96)	3.28(44)	6.08(92)	1
LIMEBURNER LAKE					
1941	26/VI	6.14(94)	5.70(79)	6.05(91)	...
	24/VII	5.91(97)	3.79(53)	5.83(94)	...
	11/IX	6.41(94)	6.34(92)	6.41(93)	...
1942	26/V	6.88(103)	5.65(73)	6.97(99)	...
	13/VII	6.01(95)	2.29(32)	5.58(86)	10
	13/VIII	5.86(97)	2.27(32)	5.65(91)	4
	17/IX	6.08(92)	4.59(69)	5.97(91)	...

TABLE VII (*continued*).

ST. PATRICK LAKE				
1941 15/IX	6.35(93)	6.26(88)	6.52(94)	...
1942 18/V	6.89(99)	6.88(91)	7.07(96)	...
8/VII	5.54(87)	4.76(69)	5.48(85)	...
12/VIII	5.54(88)	5.33(82)	5 49(87)	...
16/IX	5.88(89)	5.61(84)	5.83(88)	...
WELCH LAKE				
1941 26/VI	5.84(89)	3.78(45)	5.76(86)	...
24/VII	5.62(94)	2.28(27)	5.47(87)	2
11/IX	6.14(90)	1.86(23)	6.03(87)	1
1942 26/V	6.38(93)	1.96(22)	6.26(87)	2
13/VII	5.54(89)	0.52(6)	5.06(76)	6
13/VIII	5.64(91)	0.17(2)	5.09(78)	2
17/IX	5.80(87)	0.0(0)	5.37(79)	2

earlier these materials are largely allochthonous. Juday and Birge (1933) have noted that allochthonous humic substances which enter lakes as stains are largely carbonaceous rather than nitrogenous in character. It follows, therefore, that, although higher values for oxygen consumed and colour in Welch as compared to Crecy Lake indicated a greater organic content in the former, they cannot be construed as an index of a correspondingly greater fertility with respect to sources of nitrogen.

DISSOLVED OXYGEN. The dissolved-oxygen content of the water was determined by the unmodified Winkler method. Samples for analyses were secured with a Knudsen water bottle at metre intervals of depth in the deepest part of each lake. Temperature readings were made at the same time. Whipple and Whipple's table of saturation values was used (Ricker, 1934).

The nature of the vertical distribution of the dissolved oxygen in the eight lakes during August, 1942, is illustrated in Figures 2-4; also surface, bottom and mean values are presented in Table VII for a number of dates during the summers of 1941 and 1942.

Summer reduction in the quantity of dissolved oxygen was severe only toward the bottom in the lakes with thermally-stratified waters. As expected, summer deficits were generally minor in the shallow lakes. Nevertheless, deficits tended to develop during periods of temporary stagnation, as illustrated by the values of 4.8 ml. per litre (69 per cent saturation) on July 8, 1942, in St. Patrick and 5.3 ml. per litre (77 per cent saturation) on July 13, 1942 in Gibson Lake. In common with the oxygen-consumed values, the reduction in dissolved-oxygen content reflected the presence of a considerable amount of decomposable organic matter. This organic matter, however, was not yet in sufficient quantity to be a very disturbing influence in oxygen reduction unless the water remained unaerated for some period of time.

The mean dissolved-oxygen content of the water in Gibson Lake on March 17, 1947, while the lake was still covered with ice, was 8.5 ml. per litre (90 per cent saturation). The content varied from 9.3 ml. just under the ice to

6.4 ml. at 6 metres of depth. Although no similar data are available for the other lakes, these observations suggest that in them as well no greater deficits occur in winter than in summer, and that the absolute mean oxygen content may be higher.

Since the volume of water in the hypolimnion of each of the thermally stratified lakes comprised a small percentage of the total volume and since a serious reduction in the dissolved-oxygen content occurred only there, it followed that the volume of water in which the oxygen content was insufficient for fish life in summer was also small (Table VII). Actually the values for the mean dissolved-oxygen content demonstrated that on the whole the lake waters were well supplied with oxygen.

HYDROGEN-ION CONCENTRATION AND CARBON DIOXIDE CONTENT. The hydrogen-ion concentration, expressed as a pH value, was determined colorimetrically

TABLE VIII. Free carbon dioxide, bicarbonate (bound and half-bound carbon dioxide), and hydrogen-ion concentration (pH).

Lake and date, 1943	Depth	Free CO_2	Bicarbonate	pH
	m.	*ml./l.*	*ml./l.*	
Bonaparte Aug. 2	0	1.0	5.7	6.9
	5	1.3	6.6	6.7
	10	3.6	5.6	6.4
	15	4.5	6.0	6.2
	20	5.3	5.6	6.0
Crecy July 28	0	0.8	5.1	6.8
	3	0.7	6.4	6.9
Gibson Aug. 2	0	...	...	7.0
	5.5	1.4	5.7	6.9
Johnson July 29	0	1.2	6.7	6.9
	5	2.0	7.0	6.5
	11	5.5	6.6	6.0
Kerr July 28	0	0.9	6.8	6.8
	5	1.2	7.1	6.8
	11.5	5.0	6.3	6.0
Limeburner July 29	0	1.0	8.4	7.0
	5	1.2	10.2	6.9
	9	3.8	11.1	6.6
St. Patrick July 28	0	1.1	6.6	6.9
	5	1.2	5.6	6.8
Welch Aug. 2	0	1.3	6.9	6.8
	5	1.7	6.6	6.7
	10	8.1	5.8	5.9

with permanent Hellige standards. The method outlined by Birge and Juday (1911) was followed for the free, half-bound and bound carbon dioxide analyses. Results that were obtained in late July and early August, 1943, are given in Table VIII.

The surface water of the lakes was neutral or slightly acid, with little variation from lake to lake (pH 6.8 – 7.0). Correlated with a low dissolved-oxygen content, the pH values were depressed in the bottom waters of the stratified lakes, to 5.9 in Welch (August 2, 1943) and 6.0 in Bonaparte, Johnson and Kerr Lakes (August 2, July 29 and July 28, 1943). In these situations the free carbon dioxide was highest and reached a maximum determined content of 8.1 ml. per litre (16.0 p.p.m.) in Welch Lake. In the surface waters the carbon dioxide varied little around 1 ml. per litre.

The quantity of bicarbonates (half-bound and bound carbon dioxide) was low, or, in other words, the waters were soft and poorly buffered. The highest value for bound carbon dioxide was 5.6 ml. per litre at a depth of 9 metres in Limeburner Lake on July 29, 1943, while the mean value for the lakes was 3.3 ml. per litre. Birge and Juday (1911) classified as soft-water lakes those whose waters contained an average bound carbon dioxide content of 5 ml. per litre or less, as distinct from hard-water lakes having a content of more than 22 ml. per litre. (The name Limeburner for one of the lakes would appear to be an anomaly, notwithstanding that its waters contained the largest quantity of bicarbonate, since no limestone is found in the area.)

TABLE IX. Analyses of surface waters of the lakes, in parts per million.

	Bonaparte	Crecy	Gibson	Johnson	Kerr	Limeburner	St. Patrick	Welch
Turbidity	none	none	none	none	none	none	none	none
Alkalinity as $CaCO_3$	2.5	none	2.5	6.9	none	6.0	none	2.5
Suspended matter	1.4	1.9	1.8	2.0	1.8	1.7	1.9	1.6
Residue on evaporation at 110°C.	34.4	23.8	29.4	39.0	34.4	30.9	33.4	35.0
Silica (SiO_2)	1.6	1.5	1.3	2.2	2.0	1.6	2.2	0.6
Iron (Fe)	0.02	0.03	0.02	0.16	0.03	0.03	0.02	0.03
Calcium (Ca)	3.9	2.4	3.7	3.7	3.4	4.3	2.9	3.7
Magnesium (Mg)	1.1	0.7	1.1	1.4	1.1	1.7	1.2	1.3
Alkalis as sodium (Na)	3.9	3.6	3.9	3.0	2.4	4.0	2.8	3.3
Bicarbonate (HCO_3)	3.1	none	3.1	8.4	none	7.3	none	3.1
Sulphate (SO_4)	4.6	4.7	3.7	4.0	4.9	3.7	4.6	3.8
Chloride (Cl)	2.0	2.5	3.0	2.1	2.4	2.5	2.3	2.0
Total hardness as $CaCO_3$, calculated	14.3	8.9	13.8	15.0	13.0	17.8	12.2	14.6

MINERAL AND ORGANIC MATERIALS. Analyses of samples of surface water collected from the eight lakes on October 16, 1941, were made by the Mineral Resources Division, Department of Mines and Resources, Ottawa, through the courtesy of Mr. L. A. Leverin (Table IX). Since the analyses were made some time after storage of the water in glass bottles, the data for carbonates and

Table X. Phosphorus content of lake waters, as milligrams of P per cubic meter.

Lake and date	Surface water		Bottom water	
	Soluble	Total	Soluble	Total
BONAPARTE				
1944, Aug. 23	...	8	...	13
1948, July 20	5	15	9	19
1949, July 13	5	14	6	15
CRECY				
1944, Aug. 22	...	13	...	10
1945, Aug. 29	...	12	...	17
1946, June 17	...	16	...	16
GIBSON				
1944, Aug. 16	...	13	...	18
1945, Aug. 16	...	9	...	31
1946, June 21	...	16	...	18
July 5	...	16	...	20
July 19	...	15	...	29
Aug. 2	...	10	...	27
Aug. 16	...	14	...	16
Aug. 30	...	12	...	21
Sept. 18	...	15	...	15
Oct. 4	...	13	...	15
Nov. 1	...	14	...	16
1947, May 22	5	16	6	15
June 6	...	14	...	11
June 17	...	12	...	11
July 14	5	15	8	22
July 18	5	11	5	18
JOHNSON				
1944, Aug. 22	...	11	...	15
1949, July 20	5	7	...	...
KERR				
1944, Aug. 22	...	10	...	10
1948, July 21	5	8	7	18
1949, July 20	5	10	5	10
LIMEBURNER				
1944, Aug. 23	...	10	...	11
1946, June 24	...	23	...	15
July 22	...	14	...	13
Aug. 5	...	10	...	11
Aug. 19	...	20	...	22
Sept. 5	...	8	...	9
Sept. 23	...	12	...	11

TABLE X (*continued*).

1947, June 24	...	6	...	9
July 17	14	32	15	27
July 21	...	8	...	7
July 25	...	7	...	6
Aug. 6	...	6	...	6
Aug. 22	5	31	10	34
Sept. 2	...	7	...	8
Sept. 22	...	16	...	7
1948, June 14	5	11	5	17
July 5	5	23	5	10
July 30	9	18	5	8
Aug. 16	...	5	...	11
Sept. 8	5	7	5	21
1949, May 30	14	28	6	13
June 10	10	19	5	11
June 22	5	14	5	17
ST. PATRICK				
1944, Aug. 22	...	11	...	10
1948, July 21	5	25	6	16
1949, July 20	9	14	8	9
WELCH				
1944, Aug. 16	...	22	...	23
1945, Aug. 18	...	16	...	18
1948, July 27	5	26	5	22
1949, July 15	5	21	5	17

silica at least are not necessarily representative of the water at the time of collection. The data as a whole show, nevertheless, that the waters were poorly mineralized and that for the items least affected by the storage only minor variations from lake to lake occurred, in keeping with drainage from a common area of granite rocks and poor soils.

The soluble (phosphate phosphorus) and total (soluble plus organic) phosphorus content was determined by Deniges ceruleomolybdic method (Juday *et al.*, 1928; Robinson, 1941). Before 1946 readings were made with a visual colorimeter, but during 1946 and after a Photovolt electric colorimeter was used. Results of analyses, expressed as milligrams of P per cubic metre, are presented in Table X. Poor precision obtainable in determinations of concentrations below 5 mg. of P per cu. m. did not warrant a recording closer than >5 mg. at those levels.

More frequently than not only a trace of phosphate phosphorus was present in both the surface and bottom water. (The samples were usually analysed within two or three hours after collection to minimize errors arising from changes in the phosphate content.) The total phosphorus values also represented a limited reserve of this element in the lake waters on most occasions, averaging about 15 mg. of P per cu. m. The range in total phosphorus content was from

5 to 34 mg. per cu. m., both extremes being found in Limeburner Lake. More data of various sorts are needed to explain why the total phosphorus content fluctuated so irregularly over short periods of time in Limeburner and not in Gibson Lake, and why the only appreciable and at all persistent divergence between surface and bottom values was found in the latter. There was not any marked accumulation of phosphorus in the bottom water of the stratified lakes such as has been noted by Juday and Birge (1931).

The phosphorus content in the Charlotte County lakes was of the order that was found in soft-water lakes of Wisconsin (Juday *et al.*, 1928; Juday and Birge, 1931), of the Mount Desert Island region of Maine (Fuller and Cooper, 1946) and in Nova Scotia (Hayes, 1947). In contrast, values averaging about 50 mg. per cu. m. have been found by the writer in ponds on Prince Edward Island.

King (1931) reported the following amounts of silica, as milligrams of SiO_2 per litre, in the waters of Gibson and Welch Lakes:

	1931:	July 16	July 23	August 20
Gibson:	surface	2.25	2.64	1.72
	5 metres	3.20	3.16	2.42
Welch:	surface	–	0.90	1.68
	8.7 metres	–	1.31	1.76

These values are somewhat higher than those given in Table IX for the surface water from these two lakes on October 16, 1941, even after storage in glass bottles which would tend to increase the silica content. No doubt some part of the difference may be ascribed to annual and seasonal fluctuations.

CHARACTER OF THE BOTTOM DEPOSITS. Single samples of the superficial bottom muds (about the top 10 centimetres) were collected from the greatest depth in each lake and dried at 60°C. to a constant weight. The percentage of organic matter in these samples was determined by loss on ignition in fused-quartz crucibles. That the amount of organic material in the bottom deposits was considerable is shown by the following percentages based on single observations: Bonaparte, 32; Crecy, 19; Gibson, 33; Johnson, 33; Kerr, 25; Limeburner, 27; St. Patrick, 37; Welch, 45. The higher values were found in the deeper lakes and in those with the highest values of organic matter in the water (cf. Tables I and VI).

Plankton

PHYTOPLANKTON. Qualitative analyses were made of the open-water or eulimnetic phytoplankton in samples collected in the summer of 1948 with a number 20 plankton net. A list of species, which were kindly identified by Dr. E. O. Hughes, University of Oklahoma, is presented in Table XI.

A feature of the phytoplankton in the Charlotte County lakes was the number of desmid species. An eulimnetic phytoplankton that contains a qualitative prominence of desmids has been recognized as a definite algal association—the Caledonian (West and West, 1903; Teiling, 1916; Smith, 1924). This

TABLE XI. Phytoplankton identified from the lakes. "×" represents the occurrence of the species in question.

	Gibson 17/IX/48	Gibson 12/VII/48	Limeburner 14/VI/48	St. Patrick 21/VII/48	Welch 27/VII/48	Bonaparte 20/VII/48	Kerr 21/VII/48	Crecy 4/VI/48
Cyanophyta								
Myxophyceae								
Chroococcales								
Chroococcus limneticus Lemm.		×						
Aphanocapsa delicatissima W. and G. West	×	×						
A. elachista W. and G. West			×	×				
A. elachista var. *planctonica* G. M. Smith			×					
Microcystis aeruginosa Kuetz.	×	×	×	×	×	×	×	×
Rhaboderma sigmoidea Moore and Carter						×		
Aphanothece clathrata W. and G. West					×			
Coelosphaerium Naegelianum Ungar		×	×					
Gomphosphaeria aponina Kuetz.			×					
Hormogonales								
Anabaena flos-aquae (Lyngb.) Bréb.		×	×		×	×	×	
A. catenula (Kuetz.)	×							
Anabaena sp.				×				×
Oscillatoria spp.	×				×			
Chrysophyta								
Xanthophyceae								
Mallomonas sp.				×			×	
Chrysosphaerella longispina Lauterborn					×			
Synura uvella Ehr.				×				
Chrysophyceae								
Dinobryon bavaricum Imhof		×		×	×	×	×	×
D. cylindricum Imhof		×						×
D. divergens Imhof		×	×	×		×	×	
D. sertularia Ehr.				×	×			
Bacillariophyceae								
Melosira granulata (Ehr.) Ralfs	×	×	×					
Melosira spp.				×	×	×	×	
Cyclotella comta (Ehr.) Kuetz.				×				
Cyclotella sp.						×	×	
Tabellaria flocculosa (Roth.) Kuetz.		×	×					
T. fenestrata (Lyngb.) Kuetz.			×	×				
Tabellaria sp.					×	×	×	×
Diatoma elongatum (Lyngb.) Ag.		×						
Fragilaria crotonensis Kitton		×						
Synedra sp.			×		×			×
Asterionella formosa Hass.		×	×	×		×	×	×
Eunotia robusta Ralfs				×				
E. pectinalis (Kuetz.) Rab.			×					
Pyrrophyta								
Dinophyceae								
Ceratium hirundinella (O.F.M.) Schrank	×	×		×	×	×	×	
Peridinium cinctum (O.F.M.) Ehr.(?)				×				

TABLE XI (*continued*).

	Gibson 17/IX/48	Gibson 12/VII/48	Limeburner 14/VI/48	St. Patrick 21/VII/48	Welch 27/VII/48	Bonaparte 20/VII/48	Kerr 21/VII/48	Crecy 4/VI/48
Chlorophyta								
Volvovales								
Pandorina morum Bory					×			
Pandorina sp. (?)				×				
Eudorina elegans Ehr					×			
Tetrasporales								
Gloeocystis gigas (Kuetz.) Lagerh		×		×				×
Tetraspora lacustris Lemon. (?)			×					
Oedogoniales								
Oedogonium sp				×	×	×		
Chlorococcales								
Pediastrum Boryanum (Turp.) Menegh	×							
P. araneosum Racib		×		×				
P. araneosum var. *rugulosum* (G.S.West) G. M.Smith	×						×	
P. duplex var. *clathratum* (A. Braun) Lagerh			×					
Sorastrum americanum (Boblin) Schmidle	×	×						
Coelastrum cambricum Arch		×						
Westella botryoides (W. West) de Wildm	×		×					
Dictyosphaerium pulchellum Wood	×	×		×				
Oocystis Borgei Snow	×	×						
O. lacustris Chod		×						
Dimorphococcus lunatus A. Braun			×					
Botryococcus Braunii Kuetz	×	×	×	×	×		×	
Selenastrum Bibraianum Reinsch	×							
A. Bibraianum var. *gracile* (Reinsch) Ahl. and Tiff.		×						
Kirchneriella lunaris (Kirchn.) Moeb.	×	×		×				
Scenedesmus quadricauda (Turp.) Bréb				×				
Scenedesmus sp		×						
Zygnematales								
Mougeotia sp.					×			
Zygnema sp							×	×
Spirogyra sp							×	
Desmidiales								
Closterium sp							×	
Euastrum sp				×	×			
Cosmarium moniliforme (Turp.) Ralfs. forma *punctata* Lagerh					×			
Cosmarium sp		×		×				
Micrasterias radiata Hass. var	×			×				
M. fimbriata Ralfs	×							
Xanthidium antilopaeum (Bréb.) Kuetz				×				
X. armatum var. *polymazum* Nordst	×							
Xanthidium sp					×			
Staurastrum brevispinum Bréb. forma *major* W. & G. S. West							×	
St. avicula Bréb		×						

TABLE XI (*continued*).

	Gibson 17/IX/48	Gibson 12/VII/48	Limeburner 14/VI/48	St. Patrick 21/VII/48	Welch 27/VII/48	Bonaparte 20/VII/48	Kerr 21/VII/48	Crecy 4/VI/48
St. cuspidatum Bréb.		×		×				
St. megacanthum Lund		×				×		
St. breviaculeatum G. M. Smith		×						
St. brachiatum Ralfs				×	×			
St. paradoxum Meyen	×	×		×				
St. paradoxum var. *longipes* Nordst.				×				
St. anatinum var. *denticulatum* G. M. Smith							×	
St. lacustre G. M. Smith	×	×					×	
St. leptocladum Nordst.				×			×	
St. leptocladum var. *denticulatum* G. M. Smith	×	×					×	
St. leptocladum var. *insigne* W. & G. S. West	×	×						
St. leptocladum var. *sinuatum* Wolle forma *planum* G. M. Smith						×		
St. Johnsonii W. & G. S. West					×			
St. subnudibrachiatum var. *incisum* G. M. Smith		×						
St. pentacerum (Wolle) G. M. Smith	×	×	×			×		
St. ankyroides Wolle				×	×		×	
St. rotula Nordst.				×				
St. tohopekaligense var. *brevispinum* G. M. Smith	×							
Arthrodesmus incus (Bréb.) Hass.						×		
A. incus (Bréb.) Hass. forma *minor* W. & G. S. West				×				
A. incus var. *extensus* Andersson								×
A. triangularis var. *subtriangularis* (Borge)					×			
A. triangularis var. *inflatus* W. & G. S. West forma *robusta* W. & G. S. West							×	
Onychonema filiforme (Ehr.) Roy and Biss.					×			
Sphaerozosma excavata Ralfs	×	×					×	×
S. exiguum Turn.				×				
Hyalotheca dissiliens (Smith) Bréb.							×	
H. neglecta Racib.					×			
H. mucosa (Dillw.) Ehr.					×			

association is further characterized by the occurrence of only few species of blue-green algae, Hormogonales being especially scarce.

A desmid flora attains best development in soft waters, poor in lime, which condition most frequently obtains in waters draining areas of igneous rocks. Coincidentally, such waters are often stained with humic extractives. These water conditions were found in the lakes under study.

West and West (1903) and Wesenberg-Lund (1905) observed that the Caledonian phytoplankton was quantitatively poor. Further, there is quite general agreement among limnologists that algal production is greater in hard (eutrophic) than in soft (dystrophic) waters, even if there is not unanimity

concerning what chemical elements may be in such short supply as to limit algal growth. Thus, although no corroborative quantitative data are available, the prominence of desmids, the softness of the waters, and the varying degree of dystrophy are advanced as indices of rather low algal production in the Charlotte County lakes. It is pertinent that algal "blooms", so characteristic of fertile or eutrophic waters, have not been observed in any of these lakes, except as a result of artificial fertilization (Smith, 1948).

TABLE XII. Number of zooplankters in 10 litres of surface water of the lakes, May, 1942.

Species	Bonaparte	Crecy	Gibson	Johnson	Kerr	Limeburner	St. Patrick	Welch
Diaptomus minutus Lilljeborg	354	660	212	252	126	92	124	94
Mesocyclops obsoletus (Koch)	16	18	...	72	8	2	16	8
Epischura lacustris Forbes	...	2	...	26	...	...	156	34
Copepod metanauplii	20	296	54	24	344	258	664	162
Diaphanosoma brachyurum (Liéven)	2	2	...	...	...	2	...	...
Holopedium gibberum Zaddach	4	...	...	...	...	...	...	10
Holopedium sp.	...	...	6	...	...	...	...	...
Daphnia longispina (O.F.M.)	26	4	...	2	...	...	4	...
Daphnia pulex (de Geer)	...	...	4	...	...	...	...	...
Ceriodaphnia quadrangula (O.F.M.)	4	...	...	...	...	...	...	...
Bosmina longispina Leydig	20	6	44	30	20	14	52	12
Chydorus sphaericus (O.F.M.)	...	...	...	...	...	4	...	...
Polyphemus pediculus (Linné)	2	...	...	2	...	...	...	...
Polyarthra platytera Ehrenberg	...	16	52	4	1198	8	20	4
Trichocera sp.	...	...	...	...	4	...	8	...
Keratella cochlearis (Gosse)	2	2	8	30	28	20	48	42
Notholca longispina Kellicott	60	118	68	10	150	14	1588	28
Asplanchna sp.	...	...	...	...	...	2	...	...
Conochlus unicornis Rousselet	48	...	70	114	770	178	284	1392
Totals	558	1124	518	566	2648	594	2964	1786

ZOOPLANKTON IN THE SURFACE WATER. In late May, 1942, quantitative samples of the zooplankton were taken with a 10-litre Juday plankton trap from the 0-1 metre level at a central point in each of the lakes. The sample volumes were equalized at 100 ml. and in each case counts were made in ten one-millilitre sub-samples. The data are set forth in Table XII. In addition to the microcrustaceans listed in this table, the following species are known to occur in the plankton of at least certain of the lakes: *Sida crystallina* (O.F.M.), *Bosmina longirostris* (O.F.M.), *Leptodora kindtii* (Focke), *Diaptomus spatulocrenatus* Pearse. Limnetic rotifers that occurred in samples of plankton taken with a number 20 net during the summer of 1942, and identified by G. Morley Neal, University of Toronto, are listed in Table XIII.

By comparison with the numbers of zooplankters found in the surface waters of other lakes with diverse levels of productivity, it may be judged from the few trap samples that the quantity of zooplankton in the Charlotte County lakes was moderate. The comparison cannot be pursued further, however, since the trap samples, isolated as they were in time and space, could well be quite unrepresentative.

TABLE XIII. Occurrence of planktonic rotifers in the surface waters of the lakes, 1942: *a*—abundant; *c*—common; *f*—few; *r*—rare; . . .—not found.

	Crecy Aug. 12	Bonaparte Aug. 17	Gibson Aug. 13	Johnson Sept. 15	Kerr Aug. 11	Limeburner Aug. 13	St. Patrick Aug. 12	Welch Aug. 13	Welch Aug. 25
Conochilus unicornis Rouss.	. . .	*c*	*r*	*a*	*f*	*r*	*r*	. . .	*a*
Conochiloides exiguus Ahlstrom	. . .	*r*	. . .	. . .	. . .	*f*	. . .	*c*	. . .
Ptygura sp.	. . .	. . .	. . .	*r*	. . .	. . .	. . .	. . .	. . .
Asplanchna priodonta Gosse	. . .	. . .	*r*	. . .	. . .	*f*	. . .	. . .	*c*
Ascomorpha ecaudis Perty	. . .	. . .	. . .	. . .	. . .	*r*	. . .	. . .	. . .
Polyarthra trigla Ehr.	*r*	*r*	. . .	*c*	*r*	*c*	*r*	*r*	. . .
Diurella rousseletti (Voigt)	. . .	. . .	*r*	. . .	. . .	. . .	. . .	. . .	. . .
Trichocerca cylindricus (Imhof)	. . .	*r*	*r*	*r*	*r*	*f*	. . .	*c*	*r*
T. capucina (Wierz. & Zach.)	. . .	. . .	. . .	. . .	. . .	*r*	. . .	. . .	. . .
Monostyla bulla Gosse	. . .	. . .	*r*	. . .	. . .	. . .	. . .	. . .	. . .
Keratella cochlearis (Gosse)	*r*	*f*	*r*	*r*	*f*	*r*	*r*	*r*	. . .
K. taurocephala Myers	*r*	. . .	. . .	. . .	*r*	*r*	*f*	*r*	. . .
K. crassa Ahlstrom	. . .	. . .	*f*	. . .	. . .	. . .	*r*	. . .	*r*
Kellicottia longispina (Kellicott)	*f*	*f*	*c*	*c*	*c*	*r*	*r*	. . .	. . .
Ploesoma lenticulare Herrick	*c*	. . .	*f*	. . .	. . .	*r*	*r*	*r*	. . .
Gastropus stylifer Imhof	. . .	. . .	. . .	*r*	. . .	. . .	*r*	. . .	. . .

In his extensive study of plankton communities in fresh waters of northern United States, Eddy (1934) lists the microcrustaceans *Daphnia (pulex) retrocurva, Bosmina longispina* and *Diaptomus minutus*, the rotifer *Notholca (Kellicottia) longispina*, and the diatom *Striatella (Tabellaria) fenestrata* as predominants in lakes of sufficient depth to moderate appreciably the mean temperature of the water. It is of interest to note that, aside from judgment that might be made directly from the temperature data, the occurrence and prominence of these plankters provide indirect evidence of the moderate thermal environment in the eight lakes.

ZOOPLANKTON IN GIBSON LAKE. Weekly collections were made in Gibson Lake during the spring, summer and autumn of 1930 and 1931, and for less regular intervals in 1935. The samples were obtained by towing a number 5 marquisette plankton net, attached to a 12-inch ring, for 15 minutes over a circular course covering approximately 500 meters. Three stations were occupied in 1930 and two (stations 1 and 2) in 1931. Station 1 was located at the southern end of the lake over depths from 2 to 4 metres, station 2 in the central

part of the lake over depths from 4 to 6 metres, and station 3 at the northern end over depths comparable to station 1. Surface tows (0-1 metre) were made at each station and other tows in deeper water (3-4 metres) at station 2.

A quantitative measure of the preserved plankton was made by diluting each sample to 480 ml., transferring 20 ml. from the well-mixed sample to 8 mm. glass tubes calibrated in millilitres, and allowing the plankton to settle 48 hours.

Duplicate samples were secured in 1935 (Table XIV), and show for the most only small differences in the amount of settled plankton between samples taken from the same stratum and area of water within an hour. The three stations were usually occupied within a two-hour period. All samples were taken at about the same time of day.

TABLE XIV. Quantities of plankton in duplicate hauls from Gibson Lake, in millilitres of settled plankton per 20 millilitres of sample.

	Station 1		Station 2		Station 3	
Date, 1935	Time	Quantity	Time	Quantity	Time	Quantity
June 24	9:38 a.m.	2.1				
	9:56 a.m.	2.1				
June 26	9:39 a.m.	8.1	10:19 a.m.	5.5	11:22 a.m.	5.2
	9:57 a.m.	7.8	10:39 a.m.	5.9	11:41 a.m.	5.2
July 13	1:50 p.m.	1.1	2:35 p.m.	5.2	3:46 p.m.	5.0
	2:08 p.m.	1.0	2:55 p.m.	5.9	4:06 p.m.	4.8
July 30	9:34 a.m.	0.8	10:12 a.m.	6.3	11:32 a.m.	2.4
	9:52 a.m.	1.0	10:31 a.m.	5.9	11:50 a.m.	2.2
August 3	9:49 a.m.	1.1	10:36 a.m.	8.6	11:51 a.m.	3.7
	10:12 a.m.	1.1	11:00 a.m.	8.7	12:12 p.m.	3.7

The volumes of zooplankton (very largely microcrustaceans) obtained in the above manner are plotted against respective dates of collection in Figures 5 and 6. The methods employed in collection and measurement of the plankton have serious faults, yet the data warrant certain comments and deductions upon changes in quantity and upon distribution.

1. The quantities of zooplankton in Gibson Lake did not exhibit a pattern of discrete vernal and autumnal maxima, with low levels in mid-summer, as has been so frequently reported for other lakes (Welch, 1935). Quantities were high in May, but they continued to be equally or almost equally high on occasions during the summer, especially in 1931. In late August or during September the quantities declined. Only in October, 1930, was there the suggestion of an autumnal pulse.

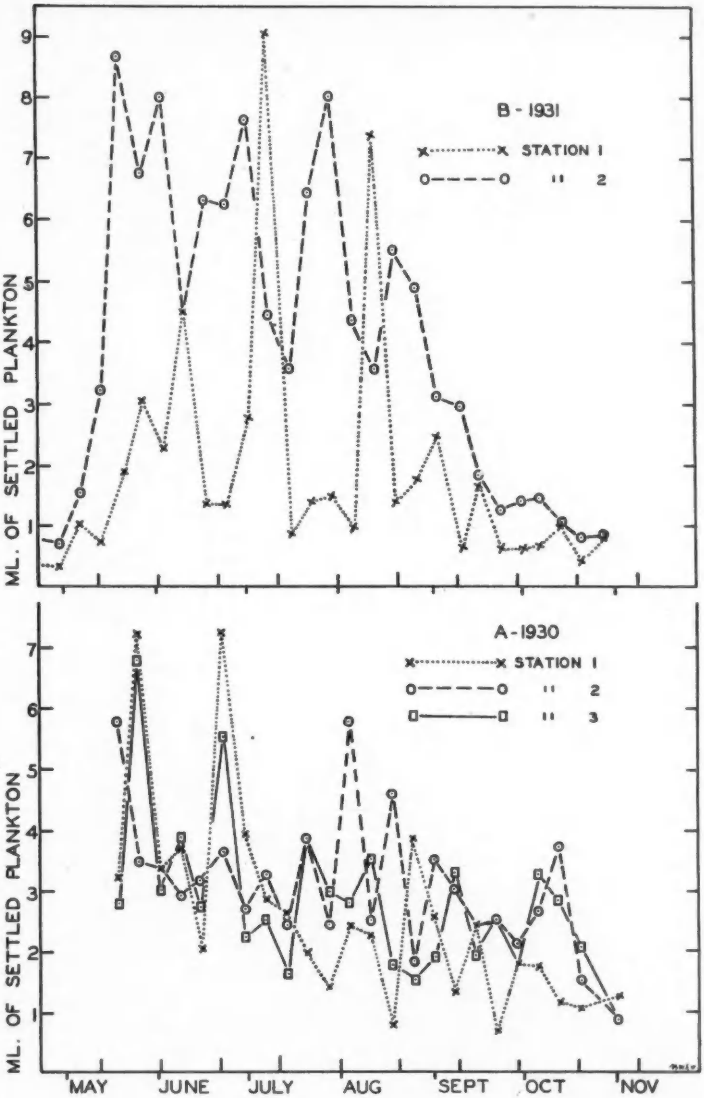

FIGURE 5. Seasonal trends in quantities of zooplankton in the surface water of Gibson Lake.

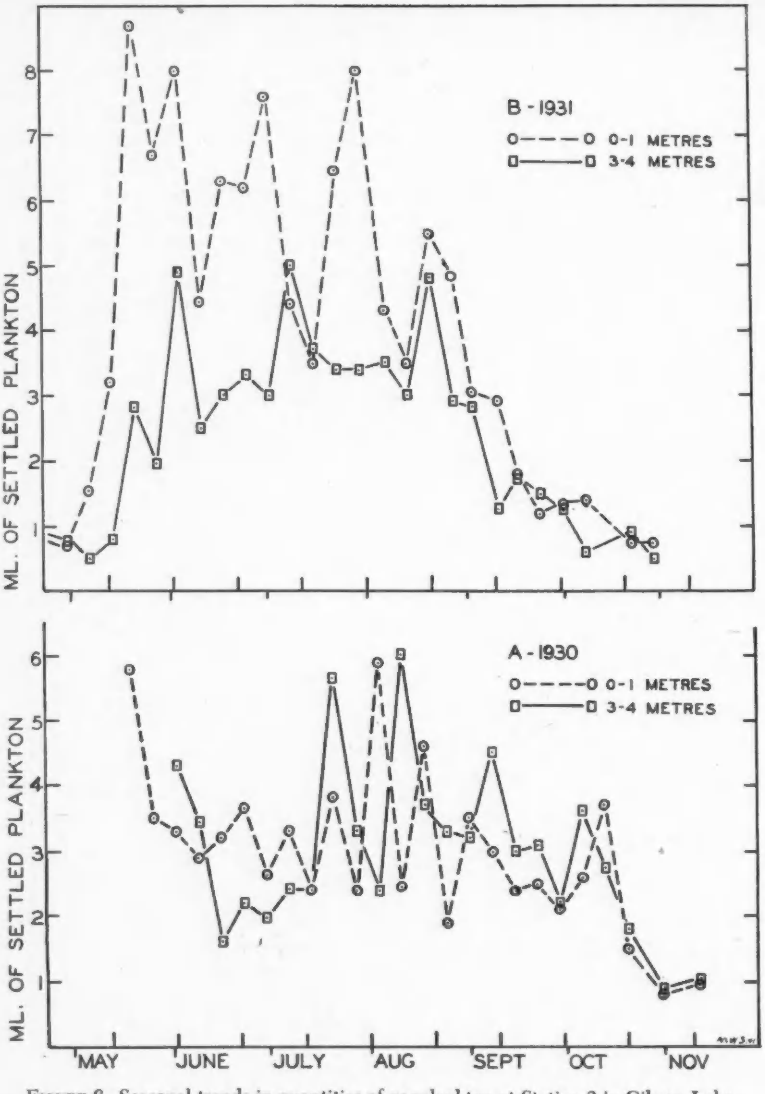

FIGURE 6. Seasonal trends in quantities of zooplankton at Station 2 in Gibson Lake.

2. An annual difference in the quantity of plankton was found, being in average appreciably greater in 1931 than in 1930.

3. During the period of the observations both uniformity and irregularity in the horizontal distribution of the zooplankters were found in the surface stratum. Irregularity occurred although there were only short distances between sampling stations (about 500 metres), and minor or no difference in depth of water. Further, Gibson Lake is quite regular in outline (Figure 1). The observed irregularities in the horizontal, as well as the vertical distribution of the zooplankters emphasize the danger of considering the zooplankton at a centrally located station as representative of the open water, in this case of a small unstratified lake.

4. The copepod *Diaptomus minutus* was the dominant microcrustacean in the lake. Subdominants were the cladocerans *Daphnia pulex, D. longispina* and *Polyphemus pediculus,* and the copepod *Mesocyclops obsoletus.* The daphnids were most plentiful in the central portion of the lake. *Diaptomus* was quite consistently the most numerous microcrustacean in all samples. *Polyphemus* was largely restricted to samples from the area of station 1, which observation is in keeping with the propensity of this species to occur in localized swarms. *Mesocyclops* was most plentiful in the deeper water. It was not found possible to ascribe a particular order in the horizontal distribution of the microcrustaceans to wind action, such as has been reported for larger lakes (Welch, 1935). Admittedly it is difficult to correlate water movements in a small lake with wind direction and force at one particular time because short distances are involved. Accordingly wind action cannot be summarily dismissed as a factor affecting distribution. However, it has been concluded that idiosyncrasies of the individual species, especially *Daphnia* and *Diaptomus,* in their active behaviour in response to environmental factors, such as light, rather than passive congregation by water movements, were most determinative of the observed variations in the quantity of zooplankton, both horizontally and vertically.

Higher Aquatic Vegetation

With the exception of Welch Lake, higher aquatic vegetation, especially the emergent type, is not a conspicuous feature of the eight lakes. In general the shores of the lakes are rocky, with narrow beaches predominantly of coarse materials, and only in sheltered coves or areas contiguous to mouths of streams have sufficiently fine soils accumulated in shallow enough water for appreciable development of rooted aquatics. In such places the shore may be muddy.

Most common to the lakes are *Eriocaulon septangulare* With., *Juncus militaris* Bigel, *Nymphaea odorata* Ait., *Nuphar variegata* Engelm., and *Lobelia Dortmanna* L., which occur where soils and depth of water are suitable, but not in extensive stands. Species of *Potamogeton,* which are usually associated with good soils in more highly mineralized waters, are minor constituents of the flora. The dominance of *Eriocaulon* and the absence of the duck weeds, for instance, characterize the waters as soft. In Table XV is presented a list, not necessarily complete, of aquatic and semi-aquatic plants, as well as those of the

immediate shore, that were collected at Kerr Lake and most of which were identified through Science Service, Department of Agriculture, Ottawa. Although referring to only one lake, it is considered that the list represents the flora of the eight lakes quite well.

Welch has the most evolved basin of the eight lakes. About 50 per cent of its area supports aquatic vegetation, in contrast to 15 per cent or less in the other lakes. *Nymphaea* and *Nuphar* are most abundant and here reach their greatest development in any of the lakes, in keeping with the occurrence of soft organic soils right to the shores of this lake.

TABLE XV. List of higher aquatic plants from Kerr Lake.

Sparganiaceae	Juncaceae
Sparganium americanum Nutt.	*Juncus canadensis* J. Gay.
	J. pelocarpus Mey.
Najadaceae	*J. militaris* Bigel.
Potamogeton natans L.	
P. Spirillus Tuckerm.	Myricaceae
	Myrica Gale L.
Alismaceae	
Sagittaria graminea Michx.	Nymphaeaceae
	Nymphaea odorata Ait.
Gramineae	*Nuphar variegata* Engelm.
Glyceria canadensis (Michx.) Trin.	*Brasenia Schreberi* Gmel.
Calamagrostis canadensis (Michx.) Beauv.	
	Droseraceae
Cyperaceae	*Drosera intermedia* Hayne
Dulichium arundinaceum (L.) Britton.	
Eleocharis Robbinsii Oakes.	Hypericaceae
E. palustris (L.) R. & S.	*Hypericum virginicum* L.
E. tenius (Willd.) Schultes.	
Scirpus subterminalis Torr.	Haloragidaceae
S. cyperinus (L.) Kunth. var. *pelius* Fern.	*Myriophyllum tenellum* Bigel.
Eriophorum virginicum L.	
Rynchospora alba (L.) Vahl.	Umbelliferae
Cladium mariscoides (Muhl.) Torr.	*Sium suave* Walt.
Carex cryptolepis Mack.	
C. Michauxiana Bock.	Ericaceae
C. crinita Lam.	*Vaccinium macrocarpon* Ait.
Eriocaulaceae	Lentibulariaceae
Eriocaulon septangulare With.	*Utricularia* sp.
Pontederiaceae	Lobeliaceae
Pontederia cordata L.	*Lobelia Dortmanna* L.
	Compositae
	Bidens frondosa L.

BOTTOM FAUNA

Data concerning bottom fauna are available for Crecy, Gibson and Limeburner Lakes (Table XVI). Nine to eleven stations along the long axis of the

lakes were occupied for each sampling. During any one year the locations of the stations were marked by buoys, which were usually lost, however, over the winter. Thus from year to year the positions of the stations were not the same, although, aided by shore features and depth of water, they were approximated closely.

Samples were taken with Ekman dredges, usually with one 9 × 9 inches (228 × 228 mm.), but on August 1 and September 3 in Limeburner and on July 3, 1947, in Gibson Lake with one 12 × 12 inches (305 × 305 mm.). In Crecy Lake the depth of water from which the samples came varied from 2 to 3 metres, in Gibson from 4 to 6 metres and in Limeburner from 5 to 9 metres. Since it was difficult to secure an adequate sample from the littoral zone with the Ekman dredge because of the firmness of the bottom soils or the presence of rocks, stones and coarse debris, only data for the deeper areas were considered.

The bottom deposits in the deeper areas varied with position in each lake and from lake to lake, but rather uniformly consisted of fine mud which contained considerable organic matter. The percentage of organic matter in dried samples of bottom mud from the deepest part in each lake was 19 for Crecy, 33 for Gibson and 27 for Limeburner. Only in Crecy Lake was bottom vegetation (*Eriocaulon* and *Isoetes*) involved in the samples.

The mean depths of Crecy, Gibson and Limeburner Lakes are respectively 2.4, 4.0 and 4.4 metres. All of the bottom area in Crecy Lake is littoral or at most sublittoral with respect to depth of water. On the other hand, the depths from which the samples were taken in Limeburner Lake may be termed profundal with reference to the occurrence of bottom organisms although it is by no means so in the literal sense of the word. The situation in Gibson Lake is intermediate.

Correlated with differences in depth of water were differences in the quality and quantity of bottom fauna. The typically littoral *Hyalella* dominated in Crecy Lake, and, together with sphaeriids and *Amnicola* for the most part, constituted a greater standing crop than found in the other lakes. The smaller standing crop in Limeburner Lake consisted largely of the more profundal forms, chironomid and *Chaoborus* larvae, while the intermediate position of Gibson in quality and quantity of bottom fauna was shown by a prominence not only of these forms but also of the sphaeriids and *Amnicola*.

Only summer samples are available. It is well recognized that the quantity of immature insects in the bottom fauna is least at that season because of emergence into imagines. Sampling at other seasons, such as early spring, would probably show higher quantities, and perhaps less disparity in quantities between Limeburner and the other two lakes since insects played a dominant role in the former.

The standing crops of bottom fauna in the three lakes were poor, being quite comparable in quantity to those in Maine lakes, concerning which Fuller and Cooper (1946, p. 62) wrote: "In summary, it may be stated that the bottom fauna is scant in Maine lakes, which are not noted for high productivity". The

quantities were decidedly less than has been found in acknowledgedly productive or eutrophic lakes such as Mendota, Wisconsin (Juday, 1922), Lake Simcoe, Ontario (Rawson, 1930), and Third Sister Lake, Michigan (Eggleton, 1931).

TABLE XVI. Bottom fauna of three lakes.

	Limeburner								
	July 4, 1946	Aug. 1, 1946	Sep. 3, 1946	July 7, 1947	Aug. 1, 1947	Sep. 3, 1947	July 8, 1948	Aug. 2 1948	Sep. 8, 1948
Number of samples	10	9	11	11	11	11	11	10	11
Area for each sample (*sq. cm.*)	533	533	533	533	755	755	533	533	533
Planaria	...	...	...	...	...	...	...	...	...
Oligochaeta	1	...	2	...	1	...	9	3	6
Hirundinae	...	...	...	...	...	...	...	...	...
Hyalella	1	...	42	2	...	...	1	16	...
Ephemera	2	1	1	4	3	...	3	...	...
Zygoptera	1	...	...	...	...	...	...	...	...
Sialis	4	2	5	3	1	1	3	2	1
Trichoptera	5	...	5	4	1	...	...	1	...
Chironomidae	37	46	48	93	71	42	50	42	33
Chaoborus	81	41	178	215	126	308	206	112	304
Ceratopogonidae	...	2	13	6	3	5	2	2	3
Misc. Insecta	1	...	...	1	...	1	...	...	...
Hydracarina	...	...	3	...	...	1	4	...	2
Sphaeriidae	22	14	8	21	14	6	6	...	1
Amnicola	5	...	1	...	...	...	...	1	1
Valvata	...	...	...	...	...	...	...	...	...
Helisoma	...	...	...	...	...	...	...	...	...
Total number in samples	160	106	306	349	220	364	284	179	351
Mean number per sample	16	12	28	32	20	33	26	16	32
Standard deviation	7.3	4.0	16.4	15.2	8.7	9.1	8.1	7.7	21.3
Number per sq. m.	301	221	522	596	265	438	485	336	599
Total dry weight in samples (gm.)	0.15	0.08	0.13	0.21	0.13	0.13	0.08	0.04	0.07
Dry weight kgm. per hectare	2.8	1.8	2.2	3.7	1.6	1.6	1.4	0.8	1.2
lb. per acre	2.5	1.6	1.9	3.3	1.4	1.4	1.3	0.7	1.1

FISH

Eighteen species of fish have been found in the eight lakes. From the information at hand, however, only four species are known to occur in all of the lakes. The cyprinids and sticklebacks noted below may well be more widely distributed in the lakes than is yet realized.

Certain indigenous and introduced species which are considered inimical to speckled trout and which are plentiful in the neighbouring larger river systems, for example St. Croix and Magaguadavic, are not found in the eight lakes. This is presumably a result of their short drainage systems and their relative isolation. Such species are white perch (*Morone americana* Gmelin),

chain pickerel (*Esox niger* LeSueur) and smallmouth black bass (*Micropterus dolomieu* Lacépède). The widely distributed yellow perch (*Perca flavescens* (Mitchill)) is found only in Bonaparte and Johnson Lakes.

TABLE XVI (*continued*).

	Gibson						Crecy
	July 2, 1946	July 31, 1946	Aug. 29, 1946	Sep. 27, 1946	June 2, 1947	July 3, 1947	June 19, 1946
Number of samples	11	11	11	11	11	11	9
Area for each sample (*sq. cm.*)	533	533	533	533	533	755	533
Planaria	...	...	...	...	...	...	16
Oligochaeta	11	10	16	7	1	...	10
Hirundinae	2	...	1	2	...	1	1
Hyalella	2	3	8	7	2	2	328
Ephemera	3	1	3	1	...	...	...
Zygoptera	...	...	3	...	...	1	2
Sialis	...	...	1	...	1	...	...
Trichoptera	...	1	...	...	...	...	4
Chironomidae	69	79	54	54	51	110	8
Chaoborus	48	60	102	127	37	150	...
Ceratopogonidae	...	4	3	2	6	...	...
Misc. Insecta	...	...	1	...	...	...	...
Hydracarina	...	1	10	2	...	...	...
Sphaeriidae	57	31	27	20	37	26	69
Amnicola	54	28	30	48	25	33	55
Valvata	...	...	...	1	1	...	...
Helisoma	...	...	...	...	...	...	3
Total number in samples	246	218	259	271	161	323	496
Mean number per sample	22	20	24	25	15	29	55
Standard deviation	9.2	8.3	11.0	5.9	6.1	8.6	31.7
Number per sq. m.	420	372	442	463	275	389	1035
Total dry weight in samples (gm.)	0.35	0.20	0.24	0.24	0.22	0.26	0.29
Dry weight kgm. per hectare	5.9	3.4	4.1	4.2	3.7	3.1	6.1
lb. per acre	5.4	3.1	3.8	3.8	3.5	3.0	5.6

Unless otherwise specified notch or fork length of fish, that is, from the tip of the snout to the end of the shortest rays in the caudal fin, is recorded.

1. *Coregonus clupeaformis* (Mitchill)—LAKE WHITEFISH. A small specimen of this species was found on the shore of Kerr Lake on July 3, 1945, by Mr. C. Lowery. In July, 1950, gill-nets placed in this lake captured 38 whitefish of which 27 that had escaped damage by eels averaged 20.6 ± 0.69 cm. in length. There are no previous records of this species in Kerr Lake, nor for that matter in any other lakes of the region (Smith, 1951).

2. *Salmo salar sebago* Girard—LANDLOCKED ATLANTIC SALMON. Landlocked salmon occur in Gibson and Limeburner Lakes, as well as in the lower lakes

of the Chamcook system. This fish is a recent addition to the fauna of Limeburner Lake, however, having entered as a result of the water diversion noted above. It is a moot point whether the salmon is indigenous or was introduced into the Chamcook lakes. Although no definite records are available, certain local information is to the effect that landlocked salmon (as well as lake trout, *Cristivomer namaycush* Walbaum, which is present in Chamcook Lake) were introduced into the Chamcook lakes about 65 years ago. On the other hand, a Captain Campbell Hardy of the Royal Engineers reported in the eighteen fifties that landlocked salmon were present in the Chamcook lakes (James Catt, personal communication). Kurata (1927, p. 202) stated: "Sebago salmon (*Salmo salar sebago*) are said to occur naturally in this lake [Chamcook]". In any case, as Wilder (1947) has already pointed out, the purity of the present Chamcook stock is questionable as a result of fish cultural activities. Rodd (1932, 1934, 1940) records the introduction of Atlantic salmon fry, two-year-old ouananiche salmon, and two-year-old hybrids between salmon and ouananiche into the Chamcook system.

In Gibson Lake the salmon has been maintaining itself for the most part more successfully than the speckled trout, although the yield of either species to the anglers has been low (Table XX).

3. *Salvelinus fontinalis* (Mitchill)—EASTERN SPECKLED OR BROOK TROUT. The lakes were selected for study because they contained speckled trout. The species is the most popular sport fish of the region and has been the mainstay of the fishery. It will be discussed more fully elsewhere in this account.

4. *Osmerus mordax* (Mitchill)—AMERICAN SMELT. The smelt is landlocked in all of the eight lakes except Crecy and Welch. Since it normally frequents the open water of the lakes and is small, this fish is not frequently taken in shore seine hauls, by gill-nets or by angling. Unless noted in tributary streams, especially at time of spawning in early spring, or in the stomachs of other fish, its presence in a lake could be missed by the casual netting for qualitative samples. For some reason, a few smelt have been observed to run into the outlet of Gibson Lake in late fall, and in November, 1945, nine specimens were captured in a fish trap maintained in that stream. These fish averaged 6.5 cm. in length (6.0 to 7.2 cm.) and 1.8 gms. in weight after preservation in formalin. From an examination of the scales they were judged to be fish of the year.

5. *Anguilla bostoniensis* LeSueur—AMERICAN EEL. The eel is ubiquitous in its distribution in the eight lakes and in the region generally. Since it grows to be one of the largest fish in the lakes, is predatory, and is a dominant of the fish populations, the eel is a most serious fish competitor and predator of the speckled trout. Destruction of an eel population by poisoning resulted in improvement of trout angling in a small Charlotte County lake (Smith, 1948). However, unless the poisoning is repetitive only temporary control of eel populations can be attained, for young eels (elvers) enter the fresh water of the region from the sea annually.

During the course of the investigations many data have accumulated concerning the eel. These, augmented by information from other maritime waters, will be presented in a separate report.

6. *Catostomus commersonnii* (Lacépède)—WHITE SUCKER. The white sucker is one of the more successful species in the lakes, with the exception of Crecy and Welch. So far as is known, this sucker is absent from the latter and rare in Crecy Lake. That the species is rare in Crecy lake is noteworthy since a population of suckers occurs in the pond on Crecy outlet, and until recently no obvious barriers prevented its penetration upward into the lake.

Spawning suckers were trapped in the outlet of Gibson Lake during May, 1947 (May 13, 19, 23, 25 and 29). Male fish predominated (80 per cent) in the composite sample of 235 specimens. However it is not thought that this disparity in the sex ratio held for the sucker population in Gibson Lake, but was biased as a result of different behaviour on the part of the two sexes in moving into and out of the brook. Age determinations were made by scale reading and were found to be rather difficult. Only 56 per cent of the first and second readings agreed, and repeat readings were necessary before reasonable confidence could be placed in the results which are given in Table XVII. Since the suckers were taken at spawning time, the ages are for full years of growth. The growth rate of the suckers from Gibson Lake proved slower than found by Spoor (1938) for this species in Muskellunge Lake, Wisconsin (especially after due allowance was made for the difference in season of capture), and intermediate for the range of growth reported by Stewart (1927) for specimens from various habitats in the Ithaca region of New York.

TABLE XVII. Average fork length in centimetres of suckers at various ages, from Gibson lake, and their standard deviation in length (s).

	Female			Male		
Age	No.	Average length	s	No.	Average length	s
IV	2	24.4	...	36	21.7	1.64
V	11	25.4	1.77	65	23.6	1.69
VI	14	27.4	1.85	60	25.4	1.48
VII	13	30.3	1.12	19	26.9	1.12
VIII	7	33.6	...	4	28.4	...

From a sample of 27 white suckers of unknown age netted in Limeburner Lake in May, 1944, the following relationships between notch and standard length were determined: notch equalled 1.16 standard length, or standard equalled 0.8 of notch length. The length range of the sample was from 26.2 to 38.0 cm.

7. *Notemigonus crysoleucas* (Mitchill)—GOLDEN SHINER. This cyprinid, which is frequently among the dominant species in other Maritime lakes, has been positively recorded only from Gibson and Limeburner (Chamcook system). There it is apparently a minor constituent of the fish populations.

8. *Semotilus corporalis* (Mitchill)—FALLFISH

9. S. *atromaculatus* (Mitchill)—CREEK CHUB. Fallfish have been found in Bonaparte, Johnson and St. Patrick Lakes, and creek chub in the first two lakes only. It was observed in 1939 that these minnows, presumably both species, although they were difficult to distinguish in the water, fed upon introduced trout fingerlings (3.2 cm. in average length) when these were planted in a weeded, quiet bay frequented by the former species. The minnows were not observed, however, to pursue the planted trout as the latter moved out of the area into more open but still shallow water along exposed shores.

10. *Chrosomus eos* Cope—NORTHERN REDBELLY DACE. This species was found to be present in Crecy Lake when considerable numbers entered traps set in the lake for eels during the summer of 1950.

11. *Rhinichthys atratulus* (Herman)—BLACKNOSE DACE. As yet *R. atratulus* has been noted only in the outlet from Crecy Lake, and in the area of that lake immediately contiguous to the outlet.

12. *Couesius plumbeus* (Agassiz)—LAKE CHUB. The species has been found in all of the eight lakes. A sample of 509 lake chub was secured during October and November, 1945, from a fish-trap in Gibson outlet. Although a certain number of this fish has been observed over a number of years to enter the outlet each year, that in 1945 was unusually large. The species enters this stream during early summer, and spawns, but no reason is apparent for the fall movement away from its normal lake habitat.

Length frequencies in the above sample are shown in Figure 7. Another sample of 55 lake chub, taken from Gibson Lake by seining in August, 1949, consisted, as far as could be determined from a study of the scales, of 6 fish of the year, averaging 3.9 cm. in length, and of 49 specimens in their second year of age, averaging 6.7 cm. ($s = 0.86$ cm.). It may be surmised from these data, when consideration is given to the difference in time of collection, and from the unimodality of the length frequencies in Figure 7, that the lake chub taken in 1945 were largely of one age and had probably completed their second season of growth.

For the 1945 sample of *Couesius* the notch length equalled 1.16 standard or 0.93 total length. Total length equalled 1.25 standard length.

It is of interest in characterizing the habitats in the Charlotte County lakes that the lake chub is usually considered a cool-water species. Further, of its occurrence in New York state Greeley (1931, p. 85) writes: "This minnow may be considered a reliable indication of trout water in this region; at least we have never found it where trout were not present or had not been present".

13. *Notropis cornutus* (Mitchill)—COMMON SHINER. The common shiner is a rather unsuccessful species in the eight lakes, and has as yet been found

in small numbers only in Gibson, Johnson and Limeburner Lakes, although one would suspect that it would occur in Bonaparte and Kerr Lakes as well.

14. ***Fundulus diaphanus*** (LeSueur)—BANDED KILLIFISH. The killifish is probably the most numerous species of fish in the Charlotte County lakes, and is conspicuous in schools on warm, calm summer days in shallow water at the

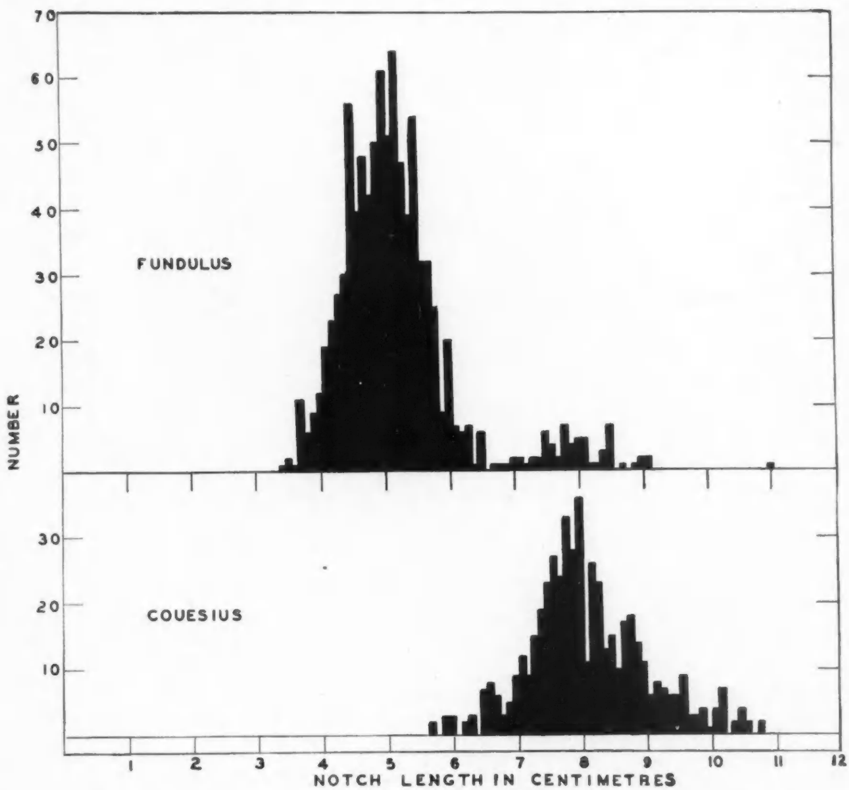

FIGURE 7. Length frequencies in samples of *Fundulus* and *Couesius* from Gibson Lake.

shore, especially over a sandy bottom. Total-length frequencies in a seined collection of this species from Gibson Lake on July 5 and 12, 1945, are illustrated in Figure 15. Since the killifish does not commence spawning until early summer, it would appear that the majority of the fish in the above collection, with a modal length at about 5 cm., were in their second summer of growth (age I), while possibly some of the larger individuals were in their third year.

15. *Gasterosteus aculeatus* Linnaeus—THREESPINE STICKLEBACK.

16. *Pungitius pungitius* (Linnaeus)—NINESPINE STICKLEBACK. Both of these sticklebacks have been identified from Crecy and Gibson Lakes. One, if not both, has been observed in the other eight lakes with the exception of Welch, but specimens are not at hand.

TABLE XVIII. Growth of yellow perch in Bonaparte and Johnson Lakes compared to that in a number of other lakes. Standard length in millimetres.

Lake and authority	Age in years completed II	III	IV	V
Erie (Jobes, 1933)	178	197	250	316
Nebish, Wis. (Schneberger, 1935)	157	173	209	245
Erie (Harkness, 1922)	144	168	187	217
Weber, Wis. (Schneberger, 1935)	130	158	174	191
Wawasee, Ind. (Hile, 1931)	129	167	198	220
Section Four, Mich. (Eschmeyer, 1938)	♀ 124	137	157	...
	♂ 115	131	...	...
Ford, Mich. (Eschmeyer, 1938)	♀ 116	127	130	131
	♂ 113	116	119	...
Winona, Ind. (Bolen, 1923)	111	137	175	..
Deep, Mich. (Carbine and Applegate, 1948)	110	140	161	...
Silver, Wis. (Schneberger, 1935)	109	120	145	175
South Twin, Mich. (Eschmeyer, 1937)	♀ 87	125	134	169
	♂ 84	116	121	...
Jesse, N.S. (Smith, 1939)	♀ 81	95	112	...
	♂ 80	95	109	...
Bonaparte, 1942	♀ 99	106	114	123
	♂ ...	98	102	111
Johnson, 1941	♀ 109	127	135	155
1942	♀ ...	124	131	148

17. *Perca flavescens* (Mitchill)—YELLOW PERCH. The yellow perch is restricted among the eight lakes to Bonaparte and Johnson. Of a sample of these fish collected by angling during the summers of 1941 and 1942, 117 individuals from Bonaparte and 71 from Johnson were in the age groups from II to V years. In Table XVIII the growth of these perch, expressed as standard length, is contrasted with that which has been determined by investigators for a variety of lakes. The comparison shows that the perch from Bonaparte and Johnson ranked among the populations with the slower-growing fish. Assuming that the growth rates of the perch reflect the trophic level of the environments, then the comparison shows further that these two lakes were relatively non-productive. A similar slow growth rate of perch may result from overpopulation, such as apparently existed in some of the Michigan lakes studied by Eschmeyer (1937, 1938). However the population of perch, as well as of other fish, was not large in either Bonaparte or Johnson Lakes, so that crowding could scarcely be involved here. In any event the slow growth is in agreement with the other indices which suggest low productivity for these lakes.

18. *Lepomis gibbosus* (Linnaeus)—PUMPKINSEED. The pumpkinseed or common sunfish is absent only from Crecy of the eight lakes studied. It appears most plentiful in Welch Lake, the most evolved of the lakes, where a good proportion of the area is sufficiently shallow to support white and yellow pond lilies, among which this species finds a favourite summer habitat. Reid (1930) studied the growth rate of the pumpkinseed from Welch Lake. Compared to what was found by Creaser (1926) for this species in Douglas and Houghton Lakes, Michigan, the growth rate in Welch was somewhat faster until the fourth year of age was reached, after which it was much surpassed by the Michigan fish.

Discussion of Limnological Conditions

Two groups of factors are prominent in determining the level of productivity in a lake. On the one hand there are those factors, termed primary or edaphic, which are referable to the character of the drainage area and, on the other, those referred to as secondary or morphometric, which are dependent upon features of the lake itself. It is readily appreciated that primarily the fertility of the waters in a lake will be directly dependent upon the fertility of the soils of its drainage area; and that secondarily those factors in the lake which determine the efficiency of utilization of the nutrient materials that have been brought into the basin, whether in good or poor supply, will condition the productive level. Of these limnetic factors, the shape of the lake basin, or more specifically the mean depth of the water, is of special concern, for in general a shallow lake is more productive than a deep one, other conditions being comparable. Thus it is the inter-play of the primary and secondary factors that determines the level of productivity in a lake. Quoting Rawson (1939), "If in any lake, all factors are favourable (harmonious), extremes of eutrophy or oligotrophy will result. In most lakes the degree of eutrophy or oligotrophy represents the balance of certain favourable factors over others of an unfavourable (disharmonious) nature".

The primary or edaphic factors have been shown to have a dominant influence upon the Charlotte County lakes and for the most part have conditioned a poor to mediocre level of production. The granitic rocks of the drainage area have weathered slowly to give rather infertile shallow soils. The drainage waters reaching the lakes are poorly mineralized, and in addition are often stained with humic extractives which are a disturbing element in the economy of a lake. Considerable diversity exists in the morphometric characters of the eight lakes (Table I), yet the influence of these secondary factors, favourable or unfavourable, has been largely overshadowed by more determinant primary factors (the limited supply of nutrient salts and the stained water) to the point where the level of production in all of the lakes appears to vary within relatively narrow limits near the lower end of the scale of productivity. In shallow Crecy Lake, which was little affected by stained water although still receiving a comparable supply of nutrients, that is, the unfavourable effects of the primary factors were least while the secondary factors

were favourable, there was evidence (bottom fauna, yield of trout) of the highest level of production among the eight lakes.

Climatic factors also have an important effect upon the productivity of a lake. The Charlotte County lakes are closely grouped and lie at approximately the same altitude but vary in their exposure to wind action. However, as with the morphometric factors, possible differential wind effects upon the productivity of the lakes are considered minor in character and masked by the strong controlling influence of the low fertility of the waters.

The Charlotte County lakes apparently date from the Wisconsin glaciation period of the Pleistocene era (Coleman, 1941) and on the whole have evolved slowly. Within recent times, at least, forest cover has kept silting from erosion to a minimum. There have accumulated very considerable, but undetermined, depths of organic muds in the lake basins, but these organic deposits do not reflect extensive elaboration of organic materials within the lakes. Rather they are an accumulation of humic materials brought in by the drainage waters. Such materials, being almost entirely carbonaceous in composition (Juday and Birge, 1933), are poor contributors to fertility, and the lakes accordingly are of the dystrophic type. Welch has the most evolved basin of the eight lakes, with extensive deposits of organic muds, and approaches senescence, but its general productive level cannot be judged to be appreciably, if at all, higher than that of the other lakes.

YIELD OF TROUT TO ANGLERS

Method of Assessment

Beginning in 1939 a schedule of closing and opening the eight Charlotte County lakes to angling was put into effect whereby in 1941 two and in subsequent years four of the lakes would be open to angling in any one year (Table XIX). This schedule permitted fishing of introduced trout when in their fourth year of age, at which age it was presumed that they would be of suitable size for angling. The original programme called for an observational period of ten years. When closed, the lakes were patrolled to prevent illegal angling.

Creel censuses were conducted to assess the yield of trout to the anglers. This programme was incompletely carried out, however, because of difficulties in obtaining census takers during the war years and immediately after. Alterations in the programme were also made toward the end of the planned observational period because of the requirements of another investigation, especially in Crecy and Gibson Lakes.

When a creel census was conducted on a lake the attempt was made to have it complete. To this end a man was hired to spend his time at one lake. An exception was Welch since anglers from that lake passed by Gibson and were contacted by the census taker stationed there. The angling season was from April 1 to September 30, but the lakes were not usually free of ice by April 1 (Table V). Further, little angling occurred after June (Table XXIII),

and only on a few occasions was it found advisable to continue the censuses through August and September. Since none of the lakes was large and since the census takers lived at or near the lakes under their charge, it is believed that practically all anglers were contacted and that an almost complete record of the angled trout (and landlocked salmon from Gibson Lake) was obtained. In addition records were taken of angling in the outlet streams.

The census taker obtained the following information from each angler fishing from shore or for each boat (which might contain more than one person), and recorded it separately for each angler or boat upon a form prepared for his use: (*a*) number of anglers (if boat); (*b*) number of trout captured; (*c*) hours of fishing to nearest half-hour whether any fish were taken or not; (*d*) manner of fishing; (*e*) length of each trout to at least the nearest half-centimetre; (*f*) weight of each trout to nearest half-ounce; (*g*) sex of trout (incompletely). A sample of scales was also taken from each fish.

TABLE XIX. Schedule for stocking the Charlotte County lakes, and closing and opening them to fishing.

	Stocking and closing year	Size of stock[a]	Opening year	Stocking year	Closing year	Size of stock	Opening year
Kerr	1939	yearlings	1941	1942	1943	No. 2 fingerlings	1945
Johnson	1939	yearlings	1941	1942	1943	No. 2 fingerlings	1945
Limeburner	1939	No. 5 fingerlings	1942	1943	1944	No. 2 fingerlings	1946
Bonaparte	1939	No. 2 fingerlings	1942	1943	1944	No. 5 fingerlings	1946
St. Patrick	1940	No. 2 fingerlings	1943	1944	1945	yearlings	1946
Crecy	1940	No. 2 fingerlings	1943	1944	1945	yearlings	1946
Welch	1941	No. 2 fingerlings	1944	1945	1946	No. 5 fingerlings	1948
Gibson	1941	No. 5 fingerlings	1944	1945	1946	No. 2 fingerlings	1948

[a]Length of trout is shown in Table XXVI.

RESULTS OF CENSUSES

YIELD OF TROUT TO ANGLERS FROM THE LAKES. A condensation of the data from the creel censuses conducted at the eight lakes during the period from 1941 to 1947 inclusive is presented in Table XX A. Certain of these data have been published in a progress report (Smith, 1946), as well as by Rodd (1942 to 1948).

The yield of trout to the anglers from any of the lakes was by no means impressive. Actually considerable patience on the part of the anglers as a whole was manifest, since it took on the average over three hours to catch a trout. The rate of capture varied from 0.1 trout per hour at Limeburner Lake in 1942 and 1943 to 0.6 per hour at Crecy in 1946. Only in the case of Crecy Lake did the annual yield consistently exceed one pound of trout per acre, though Gibson yielded a maximum for that lake of 1.09 lb. per acre in 1947. The

TABLE XX A. Yield of trout to anglers from the Charlotte County lakes.

Lake and year		Total number caught	Rod-hours of angling	Number per rod-hour	Number of rods	Number per rod	lb. per acre	lb. per 10^6 cu.ft.
Bonaparte	1942	230	585½	0.4	199	1.2	0.88	0.88
	1946	116	579	0.2	208	0.6	0.61	0.61
Crecy	1943	166	369	0.5	90	1.8	2.16	6.34
	1944	148	272½	0.5	52	2.8	1.45	4.24
	1946	139	227	0.6	58	2.4	1.43	4.18
Gibson	1944	20[a]	220	0.3	54	1.2	0.71	1.26
	1945	5[a]	138½	0.4	44	1.1	0.54	0.94
	1946	8[a]	131½	0.5	40	1.8	0.79	1.38
	1947	81[a]	334½	0.3	123	0.8	1.09	1.90
Johnson	1941	58	141	0.4	50	1.2	0.92	1.08
	1942	9	20	0.5	10	0.9	0.08	0.10
Kerr	1941	184	647	0.3	257	0.7	0.41	0.60
	1942	48	220½	0.2	101	0.5	0.13	0.19
	1945	73	183	0.4	58	1.3	0.20	0.30
Limeburner	1942	65	667	0.1	156	0.4	0.40	0.63
	1943	15	171	0.1	38	0.4	0.08	0.12
St. Patrick	1943	84	192½	0.4	74	1.1	0.71	1.45
	1944	167	300	0.6	72	2.3	0.94	1.91
	1946	138	346½	0.5	134	1.0	0.87	1.77
	1947	39	195	0.2	47	0.8	0.37	0.76
Welch	1944	26	59	0.4	18	1.5	0.59	1.75
All lakes		1994	6000	0.3	1883	1.1	0.58	0.95

[a]The following numbers of salmon were caught from Gibson Lake: 1944, 44; 1945, 47; 1946, 62; 1947, 22.

average for the lakes as a whole over the entire period was 0.58 lb. per acre. (Pounds per acre × 1.12 equal kilograms per hectare.)

The higher rates of capture and the greater yields per acre were generally from the shallower lakes. These yields may be emphasized by calculating them on a volume basis as in the last column of Table XX A. That the yields should be greater from the shallow lakes could result from at least two factors: (1) a greater efficiency of angling and (2) greater productivity of the waters. With the method of near-surface angling, which is the vogue in the Charlotte County lakes (see below), greater contact was probably realized between the lure and fish in the shallow than in the deep lakes, resulting in better rates of capture and possibly more thorough cropping. On the other hand, as has already been discussed, the favourable morphometric characters of the shallow lakes

would make for greater productivity, specifically in these cases for greater trout production, since the eel was the only serious fish competitor and predator present.

Some data upon the yield of speckled trout from other maritime waters are available for comparison and are given in Table XX B (Smith, 1947, 1948). The yield from Sutherland (Cumberland Co.) and Copper (Antigonish Co.) Lakes in Nova Scotia was somewhat above the average for the Charlotte County lakes, but quite comparable to that for Crecy. The Lakes O'Law in Cape Breton were in no way superior. In definite contrast, however, are the comparatively high yields from an artificial pond (established for 50 years or more) on the North Montague River, Prince Edward Island. For this pond, as for most other waters on Prince Edward Island, a high production of speckled trout is correlated with good fertility of the waters and their general suitability as habitats for trout. (The underlying rock formation is Neo-Permian sandstone, soils are deep, springs are plentiful, and the area is noted for good farming.) With respect to the comparison it has previously been stated (Smith, 1947, p. 5): "With our present knowledge, it would appear that the Power Dam Pond (Montague) and the Charlotte County lakes are representative respectively of the most and the least productive trout waters in the Maritime provinces".

TABLE XX B. Yield of trout to anglers from certain other lakes of Nova Scotia and Prince Edward Island.

Lake	Year	Total number caught	Rod-hours of angling	Number per rod-hour	Number of rods	Number per rod	lbs. per acre
Copper	1945	326	718½	0.5	286	1.1	1.0
(N.S.)	1946	309	684	0.5	401	0.8	1.1
	1947	159	492	0.3	325	0.5	0.6
Lower O'Law	1945	162	367	0.4	125	1.3	0.7
(N.S.)	1946	135	402	0.3	200	0.7	0.5
	1947	143	366	0.4	183	0.8	0.5
Upper O'Law	1945	20	79	0.3	27	0.7	0.1
(N.S.)	1946	37	152½	0.2	62	0.6	0.1
	1947	21	121	0.2	59	0.4	0.1
Sutherland	1945	2913	3586½	0.8	930	3.1	3.8
(N.S.)	1946	1395	2541	0.6	604	2.3	2.1
	1947	1050	2801½	0.4	509	2.1	1.9
Montague	1943	3731	...	2.5	376	9.9	...
(P.E.I.)	1944	3801	1516	2.5	358	10.6	40.7
(23 acres)	1945	3533	1632	2.2	372	9.5	44.0
	1946	3819	1634	2.3	429	8.9	37.2
	1947	3061	1723	1.8	381	8.0	34.1
	1948	2403	1351	1.8	344	7.0	22.4
	1949	3097	2144	1.4	519	6.0	30.1

YIELD OF TROUT FROM OUTLET STREAMS. Data upon the yield of trout to anglers from the outlet streams of Bonaparte, Crecy, Johnson and Kerr Lakes in certain years are set forth in Table XXI. They are incomplete for any one year, not so much however with respect to number of trout captured as to the effort involved and measurements of length. The trout from Crecy outlet were taken from two beaver ponds on that stream.

TABLE XXI. Yield of trout to anglers from outlet streams of the Charlotte County lakes.

Outlet of	Year	Total number reported caught	Rod-hours of angling	Number per rod-hour	Average notch length
					cm. (in.)
Bonaparte	1942	93	59	1.58	19.8(7.8)
Crecy	1944	77	10[a]	3.40	23.8(9.4)
	1945	66	$10\frac{1}{2}$[b]	2.29	24.2(9.5)
	1946	87	$24\frac{1}{2}$[c]	2.04	24.6(9.7)
Johnson	1941	22	2[d]	3.00	...
	1942	8	2	4.00	...
Kerr	1941	54	26	2.07	20.2(8.0)
	1942	15	15	1.00	...
	1945	13	...	...	...

[a]Rod-hours for catch of 34 trout; [b]of 24; [c]of 50; [d]of 6.

The catches per rod-hour are much higher for the outlets than for the lakes. The validity of the comparison may be seriously questioned since the rates for the outlet were established in large part on so few rod-hours and since these rates also appear biased toward high values by the character of the angling in the outlets. It is understood that the fishing there, as compared to that in the lakes, was restricted to fewer anglers who, knowing the possibilities in the stream areas, fished them when conditions, as shown by past experiences, were best for making good catches of trout.

YIELD OF TROUT WITH RESPECT TO METHOD OF ANGLING. Two methods of angling accounted for practically all of the catch of trout from the eight lakes: (1) still-fishing and (2) trolling. Fly-fishing and other methods were used so occasionally that the effort and catch by them may be disregarded.

In still-fishing as practised in the Charlotte County lakes, the line is cast from shore and by means of an adjustable float on the line the bait (worm or small fish) is allowed to sink from half-depth to near bottom, usually in five to ten feet of water. At any one lake, still-fishing was carried out from a few favoured spots around the shoreline where casts would reach desired depths.

Thus only a small area of the lake was covered by this sort of effort. At Crecy Lake no still-fishing was done, primarily because of difficulty of casting the bait into sufficiently deep water from the well-wooded shoreline.

In trolling, the bait (worm or fish), usually behind one or more spinners, is towed behind a row-boat on a line whose length varies with the speed of the boat and the depth at which it is desired to have the bait. A majority of the anglers trolling in Charlotte County lakes follow the shoreline, keeping for the most part over water from five to fifteen feet in depth. Thus it develops that in trolling also it is the littoral areas of the lake that are principally covered.

The results from still-fishing and trolling are compared in Table XXII. Trolling accounted for about 60 per cent of the effort and about 70 per cent of the catch. The greater efficiency of trolling over still-fishing is shown by the rate of 0.38 as against 0.25 trout per rod-hour. Since trolling is an "active" rather

TABLE XXII. Comparison of yields from trolling and still-fishing.

		Trolling			Still-fishing		
Lake	Year	Number	Rod-hours	Per rod-hour	Number	Rod-hours	Per rod-hour
Bonaparte	1942	180	440½	0.41	50	145	0.34
	1946	103	515	0.20	13	64	0.20
Crecy	1943	166	369	0.45	0	0	...
	1944	148	272½	0.54	0	0	...
	1946	139	227	0.61	0	0	...
Gibson	1944	16	68	0.24	48	152	0.32
	1945	0	0	...	52	138½	0.38
	1946	46	77	0.60	24	54½	0.44
	1947	20	60	0.33	83	274½	0.30
Johnson	1941	38	83½	0.46	20	57½	0.35
	1942	2	9	0.22	7	11	0.66
Kerr	1941	101	277½	0.36	83	369½	0.22
	1942	17	75	0.23	31	145½	0.21
	1945	54	148½	0.36	19	34½	0.55
Limeburner	1942	27	182	0.15	38	485	0.08
	1943	0	8	0	15	163	0.09
St. Patrick	1943	70	145	0.48	14	47½	0.29
	1944	126	219	0.58	41	81	0.51
	1946	71	205	0.35	67	141½	0.47
	1947	35	162	0.22	4	33	0.12
Welch	1944	19	38	0.50	7	21	0.33
Total and average		1378	3581½	0.38	616	2418½	0.25

than a "passive" method of angling and presumably brings the line into proximity to a greater number of fish than still-fishing, a greater efficiency was to be expected. Actually it will be surprising to many anglers of the region that the data did not illustrate a still greater superiority for trolling.

YIELD OF TROUT WITH RESPECT TO SEASON. Trout were taken from the lakes as soon as the ice left in April, and occasionally at a comparatively high rate, with the result that the average catch per rod-hour of 0.40 for this month was higher than for the others. However, most angling was carried out during May of each year, in which month 63 per cent of the total effort took 62 per cent of the trout at an average rate of 0.33 per rod-hour. The effort and catch declined each June, although the average yield was not appreciably lower at 0.32 trout

TABLE XXIII. Number of trout caught and rate of capture (number per rod-hour) in successive months. Dash indicates no angling; zero indicates some angling but no captures.

Lake	Year	April	May	June	July	Aug.	Sept.	Season
Bonaparte	1942	5(0.18)	211(0.44)	14(0.19)	...	...	...	230(0.39)
	1946	38(0.26)	62(0.25)	16(0.11)	0	...	...	116(0.20)
Crecy	1943	...	127(0.48)	37(0.37)	2(0.40)	...	...	166(0.45)
	1944	3(0.13)	80(0.45)	65(1.02)	0	...	...	148(0.54)
	1946	28(0.76)	30(0.33)	81(0.82)	...	...	...	139(0.61)
Gibson	1944	25(0.33)	37(0.31)	2(0.08)	...	...	...	64(0.29)
	1945	36(0.56)	16(0.22)	...	...	...	...	52(0.38)
	1946	2(0.19)	50(0.58)	13(0.53)	0	5(1.11)	...	70(0.53)
	1947	50(0.44)	53(0.24)	...	...	...	...	103(0.31)
Johnson	1941	...	45(0.45)	8(0.30)	4(0.47)	1(0.22)	...	58(0.41)
	1942	0	9(0.60)	0	...	...	...	9(0.45)
Kerr	1941	2(0.06)	109(0.37)	37(0.27)	26(0.24)	10(0.18)	0	184(0.28)
	1942	1(0.14)	39(0.23)	8(0.20)	...	...	...	48(0.22)
	1945	15(0.31)	28(0.41)	30(0.45)	...	...	...	73(0.40)
Limeburner	1942	13(0.10)	47(0.09)	5(0.14)	...	...	...	65(0.10)
	1943	...	13(0.11)	2(0.03)	...	...	...	15(0.09)
St. Patrick	1943	64(0.44)	20(0.45)	...	0	...	...	84(0.44)
	1944	12(0.60)	127(0.58)	28(0.45)	...	...	...	167(0.56)
	1946	48(0.44)	82(0.40)	8(0.16)	0	...	...	138(0.40)
	1947	...	39(0.24)	0	...	...	...	39(0.20)
Welch	1944	0	8(0.38)	0	18(1.31)	...	...	29(0.44)
Total number		342	1232	354	50	16	0	1994
Rod-hours		849½	3765	1107½	202½	66	9½	6000
Number per rod-hour		0.40	0.53	0.32	0.25	0.24	0	0.30

per rod-hour. From late June until the close of the season on September 30, very little angling was done in any year. July, August and September accounted for only 4.6 per cent of the total rod-hours. Data upon the yield of trout according to months are presented in Table XXIII.

It was indicated in the previous section that most angling, either still-fishing or trolling, was done in littoral or at most sub-littoral waters. When the temperature of these waters approached 20°C. in late June of each year, angling almost ceased. Anglers claimed that by that season trout could be taken only in a very "spotty" manner, if at all. Also according to the anglers' experiences neither did trolling in deeper waters produce worthwhile results, although it should be pointed out that deep trolling was not widely practised by local anglers. Rather the majority seemed content that further angling, even in deeper water, was not productive when trout stopped striking near the surface. Thus, in effect the lakes were practically closed to angling by July 1 of each year. The effective angling season in these lakes was accordingly short, extending over only eight to ten weeks. The full season, April 15 to September 15, enjoyed in Montague Pond, Prince Edward Island, is in definite contrast (Smith, 1947).

THE ANGLERS' CATCH AS AN INDEX OF TROUT PRODUCTION. In reporting the yield of trout to anglers from the Charlotte County lakes, it has been assumed for the lakes as a whole that the yield was an index of the trout production and that poor yield signified a small population.

Records for the yields over two or more successive years following a period of closure of a lake show that the take of trout in their fourth and fifth years of life was almost invariably less in the second and following years, although the number taken during the first year of angling was itself low (Table XX A). There was no evidence that an appreciable body of trout of angling size was being missed by the anglers during the first year or that the anglers' catch did not reflect the condition of the fishery. Corroborative of this view are the results of setting gill-nets in Bonaparte and Limeburner Lakes in 1944. Gill-nets (one with 2½-inch and two with 2¾-inch mesh, and having a surface area of about 3000 sq. ft. in total) were set from shallow to deep water, at the surface and sunk, in late May and early June while trout were still active in littoral waters. Fished for three days in each lake, the nets captured only four trout in Bonaparte and three in Limeburner Lake.

Previously in the fall of 1941, fish traps were placed at the mouths of three small inflowing streams and in the outlet of Kerr Lake, primarily in an attempt to account for more of the marked trout planted in this lake as yearlings in 1939 than had been taken by the anglers in 1941, and secondarily to gain information upon the spawning stock as an index of the trout population in the lake. The traps were fished from late September until December, but only on two of the inflowing streams were trout captured—23 specimens ranging in length from 15 to 33 cm. in length (24 cm. average).

These pieces of evidence, as well as other casual observations upon spawning and other activities of trout at other times, support the assumption that the

yield to anglers was a rough index of the trout production. To assume more specifically that differences in yield between lakes signified quite closely proportional differences in the trout populations is, however, less justified.

GROWTH OF ANGLED NATIVE TROUT.

The ages of the angled trout were determined from scales taken from an area above the lateral line and under the posterior part of the dorsal fin. Independent checks were made of each reading, which involved a number of scales. If agreement was not attained at the first check then additional examinations were made until there was reasonable assurance of a correct reading, or the scales were set aside as unreadable. Speckled trout scales are difficult to read, particularly if the sample involves only a few fish. A considerable part of the difficulty disappears, however, if a good series of samples is available from trout of all ages in an individual lake or stream so that one becomes familiar with the pattern of growth. Correspondence between the first and second readings of their scales varied from 70 per cent for trout from Gibson, Limeburner and Johnson Lakes to 80 per cent for the fish from Crecy Lake, averaging about 75 per cent for the trout from all of the lakes. Less than 5 per cent of the samples of scales were ultimately discarded as unreadable. The readings were made by Mrs. L. Miller.

The mean lengths and weights of the native trout in the dominant year classes found in the anglers' catches from the eight lakes during the period from 1941 through 1947 are presented in Table XXIV. (For samples of 15 individuals and more, values of the standard deviations from the mean lengths ranged from 1.62 to 4.00 cm. and of the mean weights from 26.1 to 117.8 g.) Appended to this table are some data upon the lengths of trout taken from the outlets of Bonaparte, Crecy and Kerr Lakes.

Only two trout in their second year (age I) were found among the anglers' catches from the lakes (Limeburner–16.2 and 18.3 cm.). Similarly trout in their sixth year (age V) were scarce. Five individuals of this age class (32.2, 39.0, 39.0, 39.9 and 42.0 cm. in length) were taken by anglers from Bonaparte, Gibson and Limeburner Lakes. The percentage age composition of the catches from all the lakes exclusive of the outlet streams was:

I	–	0.2%
II	–	27.4
III	–	58.0
IV	–	13.9
V	–	0.5

The relative scarcity of older trout can be explained by cropping and natural mortality. That trout in their fourth year (age III), rather than in their third (age II), should generally dominate the anglers' catches is not so readily explainable, however. It can be suggested that angling biased the picture by accounting more for the larger than the smaller individuals of the younger (age II) year class. Also closure to angling would promote some accumulation of

TABLE XXIV. Mean length in centimetres and weight in grams of angled native trout at various ages.

Lake	Year	Age								
		II			III			IV		
		No.	length	weight	No.	length	weight	No.	length	weight
Crecy	1943	49	23.4	159	66	29.8	302	17	34.0	410
	1944	39	24.3	166	15	28.9	220	...	...	...
	1946	7	24.1	174	39	29.1	291	4	30.5	312
Bonaparte	1942	46	19.4	93	117	25.7	180	28	30.8	280
	1946	27	21.3	123	56	27.0	224	32	32.2	371
Gibson	1944	2	20.1	85	9	28.3	251	6	30.5	317
	1945	1	20.0	85	5	27.2	233	...	...	...
	1946	1	29.0	...	3	27.4	264	...	...	...
	1947	2	23.1	170	10	26.1	213	...	...	...
Johnson	1941	3	25.1	175	17	29.2	281	1	38.7	595
	1942	...	...	...	1	21.9	192	...	...	...
Kerr	1941	26	21.3	113	44	26.9	204	2	37.6	610
	1942	5	24.6	...	11	26.5	...	2	30.9	...
	1945	10	23.2	126	30	28.0	235	11	29.9	297
Limeburner	1942	8	17.6	92	15	32.4	412	10	36.0	511
	1943	4	20.4	124	3	26.1	217	3	37.5	548
	1944	...	...	...	1	29.1	...	2	34.2	...
St. Patrick	1943	7	23.5	154	41	31.4	337	1	33.5	425
	1944	23	22.5	121	34	29.2	260	1	38.0	652
	1946	15	21.3	97	62	28.8	231	20	32.5	314
Welch	1944	...	...	...	1	34.0	...	...	...	...
	1945	...	...	...	2	34.2	426	...	...	...
	1946	1	23.2	...	2	25.0	...	...	...	...
Overall mean			22.0	130		29.1	263		32.4	360
Round pond (Crecy outlet)	1944	19	22.5		14	25.0		1	33.7	
	1945	8	23.9		6	27.8		...	...	
	1946	11	24.1		14	26.3		1	29.8	
Beaver pond (Crecy outlet)	1946	9	22.1		...	...	...	...	...	
Kerr lake outlet	1948	13	13.5		...	...		...	...	
Bonaparte lake outlet	1942	25	17.8		30	21.8		...	...	

age III trout. It is presumed that the trout of age I were too small to be caught by the methods generally practised on the lakes.

The eight lakes did not exhibit consistent differences in respect to the average sizes attained by the trout at various ages, nor were these sizes even consistent in any one lake from year to year (Table XXIV). For all practical purposes the growth may be considered quite similar in all of the lakes. Likewise there was not found sufficient consistency in differences that were met between the mean sizes of male and female trout to warrant a conclusion that one sex grew faster than the other. (The ratios of females to males for the three age classes (II, III and IV) which dominated the anglers' catches were respectively 1.3:1, 1.8:1 and 1.5:1.)

Ricker (1932), Cooper (1940), Cooper and Fuller (1945) and Baldwin (1948) provide data upon the growth of speckled trout in Ontario and Maine lakes. Differences in season of capture and length measurements employed do not permit precise comparisons, but in general no large disparity is to be noted between those and Charlotte County fish. The growth of trout in Moosehead Lake, Maine, was quite similar (Cooper and Fuller, 1945). Trout taken from the Rangeley Lakes from July to September attained average notch lengths of 26.1, 30.2 and 37.3 cm. in their third, fourth and fifth years of age respectively (Cooper, 1940). These rates of growth were among the most rapid found in the literature.

Yield of Trout and Limnological Conditions

The direct correlation of low fertility of the waters in the Charlotte County lakes with low yields of trout to anglers has been considered one of cause and effect, for obviously the trout production would be basically conditioned by the rather low trophic level in the lakes. However, other limnetic conditions could act adversely against trout production specifically, for it is equally obvious that even a highly productive lake would not produce trout if temperature and oxygen content of the water, poor spawning facilities, predation and competition from other fish, among other factors, created an unsuitable environment for that species. Thus it is pertinent to inquire if the full trout-producing capacity of the lakes, compatible with the fertility of the waters, was possibly curtailed by such factors.

As determined experimentally, a temperature of 20°C. is approximately the upper limit for favourable trout waters, with respect to their activities and preference, although still quite below the lethal level (Elson, 1942; Graham, 1949). In the field, Elson (1942) observed that brook trout left Lake Ainslie, Nova Scotia, to enter a brook with cooler water when the lake rose above 21°C. Baldwin (1948) also observed that this species in an Ontario lake moved from shallow water about July 1 into the region of the thermocline where the temperature was from 12° to 20°C. The writer observed in St. Patrick Lake in August, 1945, that speckled trout congregated in shallow water at shore where a spring seepage area was located when the mean temperature of the lake was estimated to be 20°C. or above (cf. Table II).

It is shown in the last column of Table II that either a considerable portion or all of the volume of water in the Charlotte County lakes was at 20°C., or somewhat above that level, during July and August. Reference has been made to the poor angling in the surface and littoral waters generally when the water temperature approached 20°C. Thus the summer temperature of the water curtailed the period of successful angling. No doubt the trout-producing capacity of the lakes was affected as well so that, for instance, feeding areas in shallow water were probably not utilized by the trout during the summer period. However, these observations do not detract too greatly from a conclusion that if other conditions, such as the trophic, had been favourable for a greater trout-producing capacity the summer water temperatures, excepting possibly those of the littoral areas, would not have prevented the realization of much of it.

A similar conclusion was made with respect to the dissolved-oxygen content of the water. As shown in Table VII, only small volumes of water in the lakes were deficient in oxygen to the point (3.5 ml. per litre–Graham (1949)) of being seriously detrimental to the well-being of trout.

The tributaries and outlets of the Charlotte County lakes present limited opportunities for the spawning of trout. Also they provide poor nurseries for the young since they are intermittent or reach low levels with relatively warm water by midsummer. Spawning within the lake basins has been observed at Crecy Lake, and presumably occurs in the other lakes, although it is only in the former that native young have been seen. It was the belief that the trout-producing capacities of the lakes were limited by the dearth of young trout, which led to stocking with young hatchery-reared fish. As shown below, however, the introduced trout, fingerlings or yearlings, contributed little to the anglers' catches, except the yearlings when angled within the season of planting or early in the next. The above belief was apparently not well founded: the stock of young native trout appeared sufficient to capitalize upon the trout-producing capacities of the lakes. Yet, when the food supply was improved by artificial fertilization of Crecy Lake, this situation did not obtain, and it was the hatchery trout that contributed most of the anglers' creels, indicating an insufficient native stock under those conditions (Smith, 1948).

As noted above, white and yellow perch which dominate the fish populations of so many lakes of the Maritime Provinces were absent or played a minor role in the eight Charlotte County lakes. The eel is probably the most serious fish predator in the lakes. The degree to which these and other fish restrict trout production was illustrated by experiences in Lake Jesse, Nova Scotia. This lake is similar to the Charlotte County lakes in basic productivity (plankton, fish population) but the availability of trout was so low in it that for years angling had been negligible. It was poisoned and yielded a standing crop of speckled trout estimated at 0.4 lb. per acre, out of a total of 20 lb. per acre consisting predominantly of white and yellow perch and eels. Three years later, after stocking with fingerlings and closure to fishing in the interim, the yield of trout to anglers was 0.9 lb. per acre in one season. Although the im-

provement was less than expected, the yield was probably quite commensurate with the trophic character of the waters (Smith, 1950).

In recapitulation, it is concluded that the relative infertility of the waters was the primary factor and the other environmental conditions were secondary factors in determining the observed trout-yielding capacities of the Charlotte County lakes.

CONTRIBUTION OF PLANTED SPECKLED TROUT TO ANGLERS' CATCHES

During the ten-year period prior to 1939, six of the eight lakes involved in this study were stocked (not all six in any one year) with No. 1 fingerling speckled trout, that is, trout that have been feeding from two to eight weeks, either by planting them directly into the lakes or in rearing ponds connected with them. The total numbers planted during the period were: Bonaparte, 50,000; Gibson, 58,000; Kerr, 83,500; Limeburner, 80,000; St. Patrick, 85,000; Welch, 10,000 (Rodd, 1931 *et seq.*). These introductions were made in the general belief that the stocks of trout in the lakes were being seriously reduced, and that the supply of young native trout was insufficient to recuperate the fishery. No organized method was adopted to determine the results of stocking; all that was available were anglers' reports, which lacked consistency. The opportunity was taken in this study, therefore, to set up a stocking schedule, and by marking the planted trout, to assess their contribution to the anglers' catches by means of creel censuses.

Procedure

STOCKING SCHEDULE. The schedule that was set up and quite closely followed in stocking the eight lakes is outlined in Table XIX. Stocking, closing and opening of the lakes to angling was arranged so that for most of the investigation four lakes were open and four closed to fishing in any year. Stocking with yearling trout during the second year that a lake was open was usually done sufficiently late in the season to escape angling pressure during that season. This condition was not realized in Gibson Lake in 1946, to which reference will be made below.

The plan of the schedule was that each lake would be opened to angling when the introduced trout had attained three full years of growth (age III). It was rather arbitrarily decided, without knowing what the growth rate of the trout in the lakes was at the time, that at such an age the trout would be of a size suitable for angling. Actually native trout in their third year of life (age II) constituted a good proportion of the catch, although the majority (about 60 per cent) were in their fourth year (Table XXIV).

SIZE OF PLANTED TROUT. One of the primary objectives in a stocking policy should be to utilize as young fish as will give worthwhile results, basing this view upon the economy of having nature rear the fish rather than feeding them artificially at considerable cost in rearing establishments. Thus the size of trout given first consideration in the stocking schedule was the fingerling or fish of

the year. However, it had long been a contentious issue whether such young trout were able to cope with the sudden environmental changes involved in being planted into a lake, not among the least of which is the scarcity of easily-secured food. Yearling or even older trout have been stocked where fingerlings had obviously failed to improve angling, or where there were reasons to suspect that fingerlings would have little chance of surviving, such as in the face of fish predation. Accordingly three sizes of trout were included in the schedule (Table XIX) in anticipation of gaining information upon their relative merits for stocking purposes in the habitats presented by the Charlotte County lakes. For more precise definition of the size of trout planted in the lakes, mean fork lengths of the several stocks are presented in Table XXVI.

RATE OF STOCKING. Ideally, stocking needs should be determined by the productive capacity of the waters with respect to the species to be introduced. Obviously such information was not available for the Charlotte County lakes, with the result that the stocking rate was reached rather deviously, partially from data upon the standing crops of fish in other Maritime lakes and partially in an arbitrary manner.

It was estimated for four Nova Scotian lakes, which were poisoned to rid them of undesirable fish, that the standing crop of each of the predatory species (white perch, yellow perch, eel) was in average about 4½ lb. per acre. Speckled trout are also predatory, occupying a not-too-dissimilar trophic niche to the above species. Thus, since the Nova Scotian lakes are similar in character of drainage area and chemistry of water it was considered that the carrying capacity of the Charlotte County lakes might approximate 4½ lb. of trout per acre independently of other species. (Eels were present in all lakes, but yellow perch only in Bonaparte and Johnson Lakes).

From the limited data available at the time upon the growth rate of speckled trout in natural waters, it was concluded that the introduced fish would attain a suitable angling size when in their fourth year of life (age III) and probably, as a minimum, would average three fish to the pound (Kendall and Dence, 1927; Ricker, 1932; Smith, 1939). Thus to realize a standing crop of 4½ lb. per acre there would need to be an average 13½ trout of the above size per acre present in the lakes. Arbitrarily disregarding the contribution that the native trout would make to the standing crop, and considering that the 4½ lb. of trout per acre were to be derived from the planted stock, it was calculated that 135 No. 2 fingerling, 27 No. 5 fingerling or 13½ yearling trout per acre should be planted to attain the desired standing crop when the trout were age III, assuming mortality rates of 90, 50 and 0 per cent respectively for the above sizes of trout (Embody, 1927).

It was on this basis that the numbers of trout indicated in Table XXVI as having been planted in the eight lakes were determined. The actual numbers planted deviated somewhat from the prescribed quotas, but not more than 3 per cent and usually less, except in the case of Crecy in 1945 when, in connection with a fertilization experiment, the number of planted yearlings was about 20 per cent over the quota.

MARKING OF PLANTED TROUT. The introduced speckled trout were marked by fin-clipping, except for three plantings of the smaller fingerlings in the early years of the investigation (Table XXVI). Two fins—adipose and one of the rayed fins—were removed in combinations that would avoid the possibility of confusing the place of stocking as a result of any movements from lake to lake within one water system. The trout were held for at least a week after fin-clipping before planting.

Once removed, the adipose fin of salmonoids usually shows minor regeneration if any (Tingley, 1945; Rodd, 1947; Armstrong, 1949; Slater, 1949). The writer also noted no appreciable regeneration of excised adipose fins among speckled trout retained in rearing ponds for extended periods.

TABLE XXV. Regeneration of clipped fins on speckled trout.

	Group 1	Group 2[a]
Fins removed	adipose and left ventral	adipose and left pectoral
Period held	Oct. 5/42 to July 6/43	Dec. 3/41 to May 14/43
Original number	200	154
Final number	94	113
Average length (*cm.*)		
Initial	8.0	14.7
Final	10.5	16.9
Percentage showing regeneration of rayed fins:		
No regeneration	30	42
Up to 25% "	21	26
Up to 50% "	25	24
Over 50% "	24	8
Regeneration of adipose fins	negligible	negligible

[a]Of 153 unmarked trout of this group held as a control, 112 were alive on May 14, 1943.

However, rayed fins are more prone to regenerate, the extent depending primarily upon the care that is taken in their removal. Two groups of young speckled trout were held in rearing ponds near St. Andrews, New Brunswick, after being marked by the removal of the adipose and left ventral or adipose and left pectoral fins (Table XXV). Although considerable regeneration occurred all regenerated rayed fins could be recognized as such. It was concluded, in agreement with Tingley (1945), that the average angler would probably fail to note many of the more fully regenerated fins on speckled trout for what they were. Only by having creel census takers trained to recognize the various degrees of regeneration would there be assurance of a good tally of marked

trout among anglers' catches. Since creel census takers were coached to recognize the marked trout, the writer is confident that few trout went undetected when taken by the anglers from the Charlotte County lakes. It is to be recalled that each group of planted trout had both the adipose and a rayed fin removed.

Contribution and Survival to Anglers' Catches

When the introduced trout were not angled until they were in their fourth year of age, they contributed little to the anglers' catches, as may be seen in Table XXVI. The best percentage contributions were experienced in Gibson Lake (1941 planting of yearlings) and Limeburner Lake (1939 planting of No. 4 fingerlings), but the number of trout involved was so small that these percentages (15.0 and 13.8) were of little practical significance. It followed that the survival of the introduced trout to the anglers' creels was disappointingly low, being one per cent or less.

On the other hand when yearling trout of angling size were planted and then angled during the same season or early the next, as occurred in Gibson Lake in 1947 and in Crecy in 1946, it was found that the planted trout made good contributions to the anglers' take and survival was much higher. Yet the very considerable number of these larger yearling trout that were not accounted for by the anglers still emphasized the inefficiency of the procedure in these lakes. Usually the yearling trout were planted so late in the season that anglers did not molest them, simply for the reason that they did not know the trout were in the lake or thought that it was not worthwhile going after them so soon after being planted. This situation did not obtain in Gibson Lake in 1946, however, for a group of anglers discovered the yearlings had been planted on June 30, and from August 25 until September 30, when the season closed, they took 201 of the original number of 772 introduced. These trout made up 95 per cent of the anglers' yield for the 1946 season in Gibson Lake—a survival to the creels of 26 per cent. Partly in connection with a new investigation, Gibson and Crecy Lakes were open to angling in 1947 and 1946 respectively, a year after both lakes were stocked with yearling trout. It may be seen in Table XXVI that these yearling trout also made a major contribution to the anglers' catches when exploited within a year from stocking. Such was not the case, however, with fingerling trout. None of the 6-centimetre trout planted in Gibson Lake in 1945 was taken in 1946 nor in 1947.

The results of the creel censuses showed that native trout very largely sustained the fishery, even if at a rather low level, and were utilizing the trout-producing capacity of the lakes quite fully. Introduced fingerling trout contributed so little to the anglers' catches that it could be concluded that their introduction into the Charlotte County and similar lakes was not a worthwhile procedure. Even the stocking of yearling trout of angling size gave reasonable returns only if the fish were angled during the year of stocking or early in the next. In other words the lakes were used largely as retaining rather than as rearing areas, and even as retaining areas not too effectively. It was disappointing to note that the bases upon which the stocking schedule was developed bore

TABLE XXVI. Contribution and survival of planted trout to anglers' catches. All planted trout were marked by removal of the adipose and one other fin, except as noted.

Lake	Trout planted			Census year	Total catch of trout	Catch of marked trout		
	Year	Number	Av. notch length, cm.			Number (year planted in brackets)	Percentage of total catch	Percentage of number planted
Bonaparte	1939	13842[c]	3.2	1942	230	...	...	...
	1943	2847	12.2	1946	116	0	0	0
Crecy	1940	6976[c]	3.1	1943	166	...	...	...
				1944	148	...	...	...
	1944 1945	675 812	28.3 19.2	1946	139	5(1944) 69(1945)	3.6 49.6	0.7 8.5
Gibson	1941	1537	14.7	1944	20	3	15.0	0.2
				1945	5	0	0	0
	1945	1508	6.0	1946	211	0(1945) 201(1946)	0 95.3	0 26.0
	1946	772	22.0	1947	81	0(1945) 70(1946)	0 86.4	0 12.3[a]
Johnson	1939	461	12.7	1941	58	1	1.7	0.2
				1942	9	0	0	0
Kerr	1939	2384	12.7	1941	184	13	7.1	0.5
				1942	48	0	0	0
	1942	4994	7.5	1945	73	2	2.7	0.1
Limeburner	1939	3464	#4 fingerlings[b]	1942	65	9	13.8	0.3
				1943	15	2	13.3	0.1
St. Patrick	1940	10535	4.0	1943	84	0	0	0
				1944	167	0	0	0
	1944	1065	28.3	1946	138	10	7.2	0.9
				1947	39	0	0	0
Welch	1941	5712[c]	#2 fingerlings[b]	1944	26	...	...	...

[a]Calculated upon a presumed survival of 571 yearlings at the close of the 1946 angling season; calculated on number introduced, survival was 8.1 per cent.
[b]Measurements not available.
[c]Not marked.

little relationship to what was realized from the introduction of the varying numbers and sizes of trout.

Fate of Planted Trout

Relatively low fertility has been advanced as the basic cause of the poor trout-producing capacities of the lakes. Presumably this condition, which limited the food supply, would act as adversely against the introduced as against the native trout. Actually the results of stocking suggest strongly that this and other secondary adverse environmental conditions (summer water temperature, competition and predation, poor nurseries for the young) resulted in a differential mortality rate favouring the native trout. It has been noted that the anglers' catches consisted largely of native trout, except in the special case where yearlings were captured soon after planting. The removal of fins in marking, especially the paired ones, may also have contributed to a differential mortality. Foerster (1936) found that young sockeye salmon, when marked by removal of a ventral fin and the adipose, or part of the dorsal, had less survival potential during two years of ocean life than unmarked individuals. A similar situation was reported by Ricker (1949) for small fingerling largemouth bass when in the presence of predators, but not for two-year-old bluegills and red-ear sunfish.

That a differential mortality rate did not obtain in these lakes could be reasonably contended only (1) if the stock of young native trout was very much greater than that introduced, in order to provide, at an equal mortality rate, the number of native fish that were in the lakes, (2) if the hatchery trout were less catchable and thus less cropped than native fish, or (3) if most of the hatchery trout moved from the lakes into which they had been planted. There is no evidence of a large supply of young native trout or of an appreciable residual stock of introduced trout left in the lakes after being open to angling; however, some movement of the introduced trout away from the lake of planting was observed.

The movements of planted fingerling trout were followed closely in Bonaparte and Limeburner Lakes in 1943 (Smith, 1944). The young trout dispersed quickly from the point of planting in these lakes, often in rather discrete schools of some dozens or even hundreds which could be observed to follow the shoreline in shoal water. (This propensity of the planted trout to remain in schools for considerable time after planting would favour predation by fish, birds, etc.) In both lakes a good proportion of the planted trout fingerlings moved until they encountered running water (the normal habitat of the species at that age) and thus entered the tributaries of the lakes. In Limeburner Lake, but not Bonaparte as far as could be determined, they also entered the outlet.

Previously in 1942 five trout which had been planted in Gibson Lake in 1941 were captured in the outlet from Limeburner to the Chamcook system. Four additional specimens of this same stock were angled from Limeburner on May 27, 1942. Other attempted movements from Gibson Lake by planted trout were disclosed by their capture in a fish-trap maintained in the outlet of that lake during the summer and fall of each year since 1945. The numbers of

these trout taken in any one year varied from 0 in 1945 to a maximum of 44 in 1946; most of these were yearlings. The numbers were not more than 6 per cent of the current year's stocking.

Planted yearling trout also moved from Crecy Lake. In 1945 out of a recorded catch of 66 trout taken from the beaver ponds on Crecy outlet, 12 were marked individuals from a group planted in the lake during the previous December. However, for the period from 1944 to 1948 these were the only marked specimens in a total recorded catch of 306 trout from the outlet. Other yearlings and fingerlings planted each year after 1945 had presumably an equal chance to leave Crecy Lake, but there have been no observations that they did. The 1944 yearling stock, a part of which ran from the lake, consisted of larger fish (average 28.3 cm. in length) than subsequently planted (average from 19.2 to 21.4 cm.), and were planted about four months later than the others, which facts may have had a bearing upon the seeming difference in movements.

None of the marked No. 5 fingerlings planted in Welch Lake in 1945 were found to have moved downward into Gibson Lake where a creel census has been conducted annually since 1946. Planted trout were not found among those angled from Bonaparte and Limeburner outlets (Table XXI).

The data do not disclose any apparent consistency on the part of the various groups of planted trout in moving from the lake where they were introduced. Size and maturity of the fish, as well as the variations in water conditions, perhaps notably the height of water in the tributaries and outlets, no doubt had influences. In summary of the data at hand, the opinion is held that movements from the area of planting, although contributory, were not a major factor in the disappearance of the planted stocks. This is especially true of those introduced as fingerlings, for the small fish on moving tended to enter tributaries from which any survivors would presumably re-enter the lake of stocking.

DISCUSSION

The majority of lakes in New Brunswick and Nova Scotia have the common feature of lying in drainage areas with igneous rock formations. Devonian granites and Precambrian quartzites underlie the principal lake districts of the two provinces (Can. Dept. Mines. Geol. Surv., Map 39A, 1927, and Map 259A, 1931). Thus the data that have been accumulated upon the environments and fish production in the eight Charlotte County lakes have more than local significance, and the deficiencies found in them with respect to fish production as a whole, and trout production in particular, may be expected to obtain quite generally in similarly located lakes of both provinces.

Environmental conditions in lakes may be intentionally altered by man for better fish production. The degree to which such alterations can be made diminishes with increasing area and volume. Practical procedures can be adopted to maintain and improve the fisheries, although it must be admitted that the majority of such procedures are still in the developmental stages. There

is the hope that many limnological deficiences may be corrected, with costs in keeping with the benefits derived.

The study of the eight Charlotte County lakes has revealed a number of deficiencies which curtail production of the desired trout. Poor mineralization of the waters and the seeming scarcity of nutrient salts have exerted a basic influence. A direct approach in overcoming this deficiency is artificial fertilization. Tests are in progress at Crecy and Gibson Lakes upon the effects of adding commercial fertilizers, with as yet rather indifferent success in improving the yield of trout to anglers, although the growth rate of trout has increased to the point where yearlings have attained angling size (21 to 24 cm. in average length). This rate of growth has not previously been experienced in these and other Charlotte County lakes (Smith, 1948).

Competition and predation by undesirable species of fish are factors inimical to trout but were not so unfavourable in the eight lakes in Charlotte County as has been noted elsewhere in the Maritimes (Smith, 1938, 1940). Poisoning has been widely practised in recent years to control unwanted fish (Smith, 1950). Some such means of control should precede fertilization where undesirable fish are prominent, for otherwise any improvement in food supplies through fertilization would favour the unwanted species as much as the trout, if not more.

The severity of predation by fish-eating birds and mammals is not known, but an attempt to control and assess losses in this direction was initiated in Crecy Lake in 1949. Loons and kingfishers, although not plentiful, are resident on the eight lakes, and mergansers are migrant visitors. If bird control should prove an important measure in reducing trout mortalities there would remain the vexing question of applying it in a practical and economical manner to more than a few lakes.

Stocking is a time-honoured procedure whose efficacy in bettering angling in general and trout fishing in particular has been widely and seriously challenged in late years. The poor contribution of planted trout, especially fingerlings, to anglers' catches in the Charlotte County lakes is a common finding. However, when the native stock of young trout is too small to capitalize fully upon existing or improved trout-producing capacities of lakes, hatchery stock is needed and makes a favourable contribution (Smith, 1948). An extreme of this situation is the stocking of suitable waters barren of trout. Accordingly, stocking is most economical when applied as a procedure to overcome a deficiency in numbers of young fish, with the intent that most of their growth be attained under natural and not hatchery conditions. Yet if measures designed to increase the trout-producing capacities of lakes cannot be made effective, and angling pressure intensifies to a point of depletion of native stocks, recourse can only be had to a general programme of planting trout of angling size, with anticipation of capture soon after distribution. Actually if such fish are not taken during the season of planting, returns to anglers are disappointingly small (Table XXVI). In any event it is a programme of last recourse, and, being costly if extensively applied, would appear warranted only if a good portion of the cost were borne by the anglers concerned.

SUMMARY

Limnology

Conditions were investigated in eight Charlotte County lakes, New Brunswick, ranging in area from 20 to 73 hectares (50 to 180 acres) and in mean depth from 2.4 to 7.0 metres (7.8 to 23.0 feet).

Summer thermal stratification of the water was strongly developed in three and poorly in two of the eight lakes, while in the remaining three the waters were subject to mixing throughout by winds. On the whole the lakes presented a relatively cool environment in summer. Near-depletion of dissolved oxygen occurred in the bottom waters of the stratified lakes.

Values for oxygen consumed and colour of water (humic extractives) were positively correlated. Much of the organic matter in certain of the waters consisted of such extractives brought in by the drainage rather than from elaboration within the lakes.

Lying in an area of granite rocks and infertile soils, the waters were poorly mineralized and soft. Plant nutrients appeared generally in short supply.

Desmids were prominent qualitatively in the phytoplankton; and this prominence has been considered an index of a limited algal production. Algal "blooms" were not observed.

The zooplankton was moderate in quantity and dominated by species, such as *Diaptomus minutus,* characteristic of temperate lakes with sufficient depth to maintain a cool mean temperature of water.

Rooted aquatic vegetation was a minor feature of the lakes, except in the one most evolved (Welch) where about 50 per cent of the area supported *Nymphaea odorata* and *Nuphar variegata.* These two species and *Eriocaulon septangulare, Juncus militaris* and *Lobelia Dortmanna* were the principal constituents of the larger flora in the lakes.

Hyalella, Amnicola and sphaeriids in the shallow and *Chaoborus* and chironomid larvae in the deeper lakes were the dominant organisms of the bottom fauna, summer standing crops of which were quantitatively poor.

Eighteen species of fish were present in the eight lakes. Speckled trout, eel, lake chub and banded killifish were found in all; landlocked salmon occurred in two. Yellow perch, which were also restricted to two lakes, grew much more slowly than when in warmer eutrophic waters. The eel was considered the most serious fish predator present.

Poor mineralization (infertility) primarily and the stained character of the drainage waters (dystrophy) secondarily conditioned a poor to mediocre level of production in the lakes and largely overshadowed the effects of diversity in the morphology of the lake basins, which otherwise might have been expected to produce a greater disparity in production between the deep and shallow lakes than was observed.

Yield of Trout to Anglers

The yield of trout to anglers was assessed by creel censuses maintained on the eight lakes according to a scheme of stocking, closure and opening

whereby four of the lakes were open to angling in any one year. The original programme called for an observational period of ten years and creel censuses for four years on each lake, but it was somewhat curtailed.

The rate of capture varied from 0.1 to 0.6 trout (and landlocked salmon) per rod-hour, and averaged 0.3. The maximum annual yield encountered was 2.42 kilograms per hectare (2.16 lb. per acre) and the average for all lakes 0.65 kilograms (0.58 lb.). The higher rates of capture and greater yields per unit area were generally from the shallower lakes. The average yield of trout was among the lowest which have been determined for Maritime fresh waters.

Trolling with bait accounted for about 60 per cent of the effort and about 70 per cent of the catch. Still-fishing with bait accounted for almost all the remaining effort and catch.

Most angling was done in the littoral or sub-littoral zones. Coincident with a rise in water temperature in those areas to about 20°C. in late June, angling almost ceased. Trout were then only sporadically taken there, having presumably stopped biting and/or retreated to deeper water where they were fished only occasionally without appreciable returns. The effective angling season in the lakes was restricted to about ten weeks.

Netting, trapping and observations of spawning runs provided no evidence of poor cropping by the anglers or an appreciable residual stock which would negate the opinion that the yield to the anglers reflected generally the trout-producing capacities of the lakes.

The age composition of the anglers' catches of native trout exhibited a dominance of fish in their fourth year of life. Less than 1 per cent of the catches consisted of trout in their second and sixth years. The average sizes did not conform with such limnological differences as were found between the lakes, or in any one lake in different years, leading to the conclusion that the growth rate was quite similar in all of the lakes. Females outnumbered males at a maximum of 1.8 to 1 among the catch of trout in their fourth year.

A limited food supply, resulting from relatively low fertility of the waters, was the basic reason for the low production of trout. Summer water temperatures above those preferred by trout, competition and predation by other fish, and predation by fish-eating birds and mammals were secondary contributory factors.

Contribution of Planted Speckled Trout to Anglers' Catches

Introduced fingerling and yearling trout contributed little to the anglers' catches when these fish were not angled until in their fourth year of age. The stocking of yearling trout of angling size provided favourable returns only if angled during the year of planting or early in the next season. The fishing was largely maintained by native trout, which discredited the premise that the supply of young native trout was insufficient to utilize the full trout-producing capacity of the lakes.

The results of the investigation suggested that the native trout withstood adverse conditions of the lake environments better than the introduced stock.

Some introduced trout moved from the lakes into which they were planted, but there was not evidence that such movements were extensive enough to account for the seeming better survival of the native trout.

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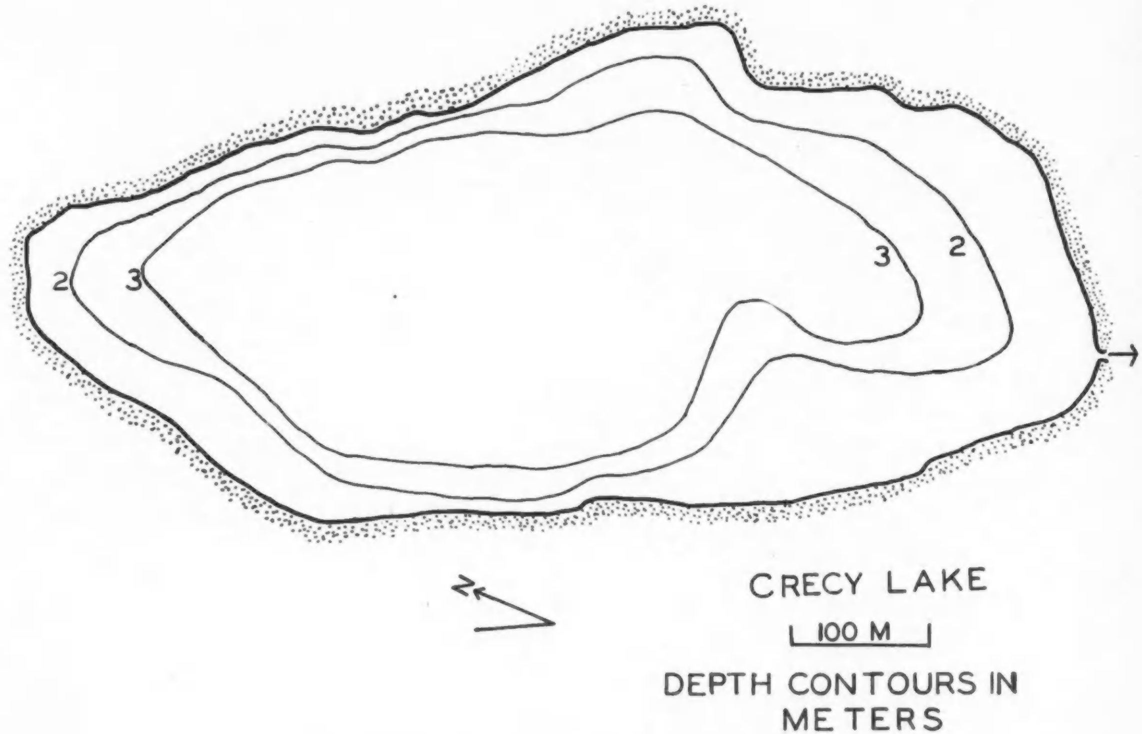

FIGURE 8. Map of Crecy Lake.

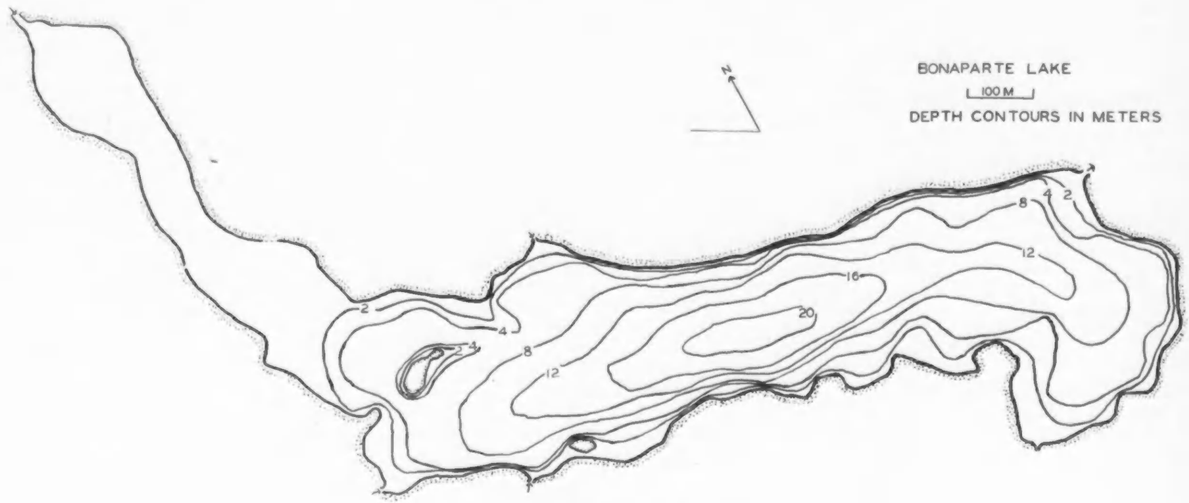

FIGURE 9. Map of Bonaparte Lake.

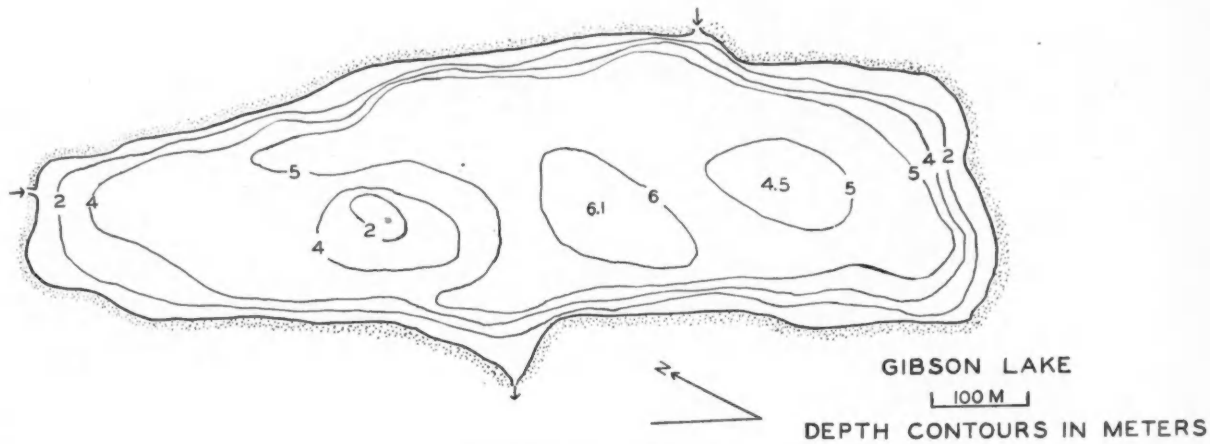

FIGURE 10. Map of Gibson Lake.

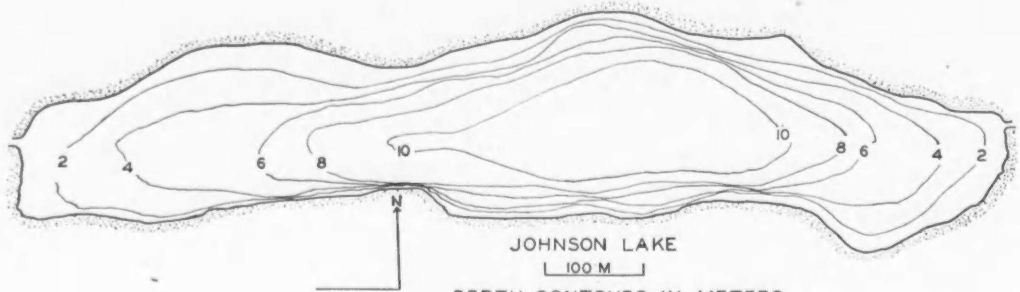

FIGURE 11. Map of Johnson Lake.

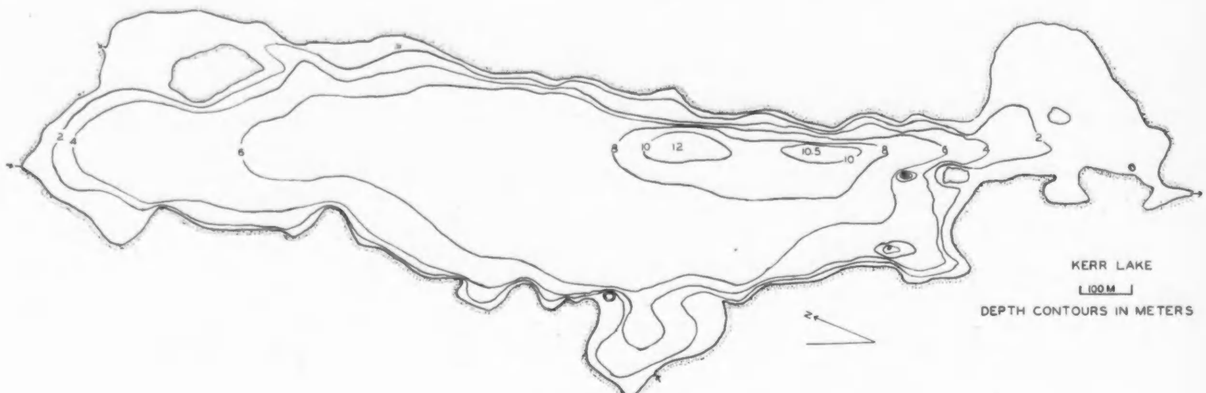

FIGURE 12. Map of Kerr Lake.

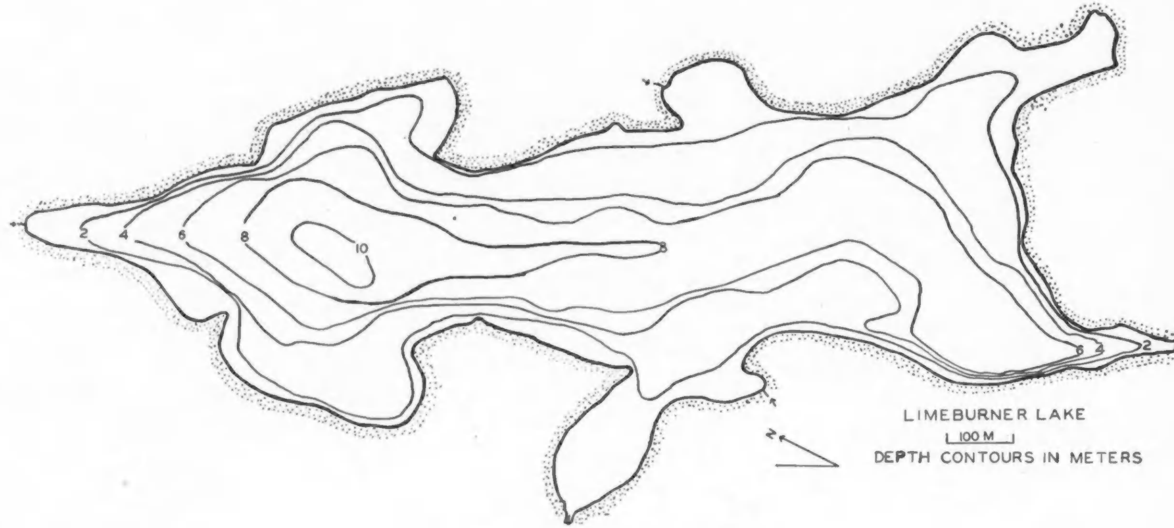

FIGURE 13. Map of Limeburner Lake.

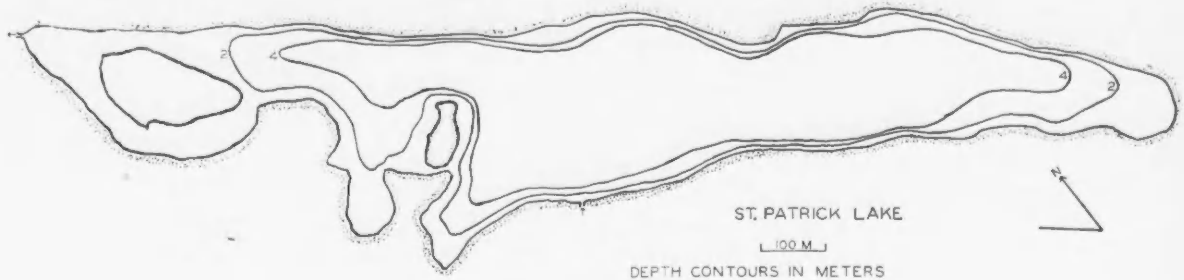

FIGURE 14. Map of St. Patrick Lake.

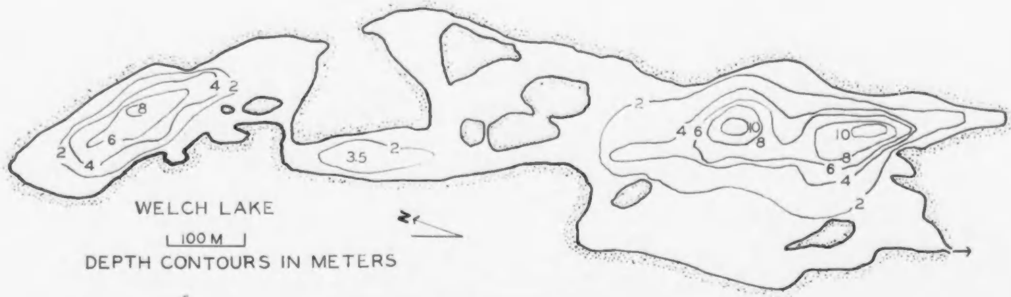

FIGURE 15. Map of Welch Lake.